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TECHNICAL REPORT NO. 66-92

INTERIM REPORT NO. 3, PROJECT VT/4051

July 1964 through March 1966

TELEDYNE INDUSTRIES
GEOTECH DIVISION
GARLAND TEXAS

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July 1964 through March 1966

by

LRSM Staff

Availability

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GEOTECH DIVISION
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15 October 1966

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ABSTRACT

The progress of the Long-Range Seismic Measurements Program (LRSM) during the period 1 July 1964 through 31 March 1966 is described. The data contained in the report are categorized along the same lines as the organization of the LRSM program, namely: operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects.

During November 1964, a program was initiated whereby several mobile observatories were transferred from the LRSM Program to other organizations. As a result, the number of observatories within the group was decreased from 39 to 16. Emphasis continues to be placed on the advantages realized by the operation of portable seismograph systems, and during the report period, the six LRSM portable systems were extensively used.

Several equipment modifications were incorporated into standard system configuration. These modifications included the installation of remote centering and free-period adjustment units on all long-period seismometers, the installation of one experimental multiconductor cable system and one prototype lightning protection system, the replacement of the tape transport supply motors with a viscous brake type of supply unit, and the installation and integration of telemetry equipment in the LASA and TFSO Extended Array observatories.

The established equipment and seismogram evaluation programs continued to lend important support to the field teams. These efforts have been a major causal factor in the professional status achieved by the field personnel.

The number and variety of specialized uses to which LRSM data can be put have grown steadily. Studies which have been undertaken and completed by the Evaluations Group include surveys of seismological bulletin data, effects of site geology on signal and noise properties, and new data processing and calibration techniques.

INTERIM REPORT NO. 3, PROJECT VT/4051
July 1964 through March 1966

1. INTRODUCTION

The Long-Range Seismic Measurements Program (LRSM), a VELA-Uniform project, was first contracted on 1 June 1960. The VELA-Uniform research project is directed towards creating major advances in all areas of seismic detection, identification, and location techniques, to the end that a better understanding of the detection and identification of underground nuclear explosions will be achieved.

Geotech's LRSM program has, for nearly 6 years, provided a majority of the detection and recording systems in support of the VELA-Uniform objectives. A vast amount of data is presently available on a nonclassified basis for use in arriving at a technical assessment of the effectiveness of a test-ban control system. In addition, these data are available to others in the scientific community for use in many varied studies.

Three technical reports have been written covering the work performed in the LRSM program previous to the time period covered by this report:

a. TR 61-3, Final Report on Phases I, II, and III, Long-Range Seismic Measurements Program, covers work performed from 1 June 1960 through 31 December 1960.

b. TR 62-22, Interim Report on Operating Procedures, Project VT/074, records the LRSM activities from 1 September 1961 through 31 December 1962.

c. TR 66-78, Interim Report No. 2, Project VT/4051, for the period 1 January 1963 through 30 June 1964.

This report describes the work performed during the period 1 July 1964 through 31 March 1966 under Project VT/4051. This project number was assigned to the LRSM program on 1 June 1963; five supplemental agreements have since been negotiated on this basic contract. The last agreement covers the operation of the LRSM program from 3 January 1966 through 31 March 1966 and the manufacture of 16 Timing Systems, Model 19000, during the summer of 1966. Since 1 April 1966, the operation of the LRSM program has continued under Project VT/6703.

Technical Reports 61-3 and 62-22 were published by The Geotechnical Corporation. Technical Report 66-78 and this report were published by Teledyne Industries, Geotech Division.

LRSM has continued to operate with the same basic purpose described above since 1960. The organizational structure has undergone only minor changes and sustains the flexibility and operating efficiency required for a field-oriented program. Figure 1 shows the organization of the LRSM program on 31 March 1966.

As would be expected, several equipment changes and modifications have been made to the LRSM system. The most notable innovation in the program has been the design, manufacture, and operation of the Portable Seismograph System, Model 19282. Extensive system modifications were required with the participation of the LRSM mobile observatories in the deep-hole seismograph research programs, the LASA subarray monitoring, and the Tonto Forest Observatory Extended Array experiment. These and other specialized activities are reviewed in this report.

2. SUMMARY

2.1 GENERAL

The operations and technical information in this report (sections 3 through 9) is a comprehensive review of the LRSM program during the specified period. The material is presented so as to best meet the requirements of researchers whose interests are in specific areas of the program; namely, operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects (data reduction). The following paragraphs in this section summarize the information contained in this report.

2.2 OPERATIONS

The number of mobile observatories was reduced from 39 to 16 units; however, 6 portable systems became operational. The portable seismographs have provided a flexibility of operations in the LRSM program which was heretofore impossible. The mobile and portable systems provided support for several projects directly related to the VELA-Uniform program. Several experimental programs involving deep-hole seismographs, in which the LRSM observatories participated, were concluded during 1964-1966. At the present time, LRSM operates no stations which include deep-hole instrumentation. The most complex systems which were operated during the past 2 years were undoubtedly the LASA-based stations and the observatories which formed the Tonto Forest Extended Array.

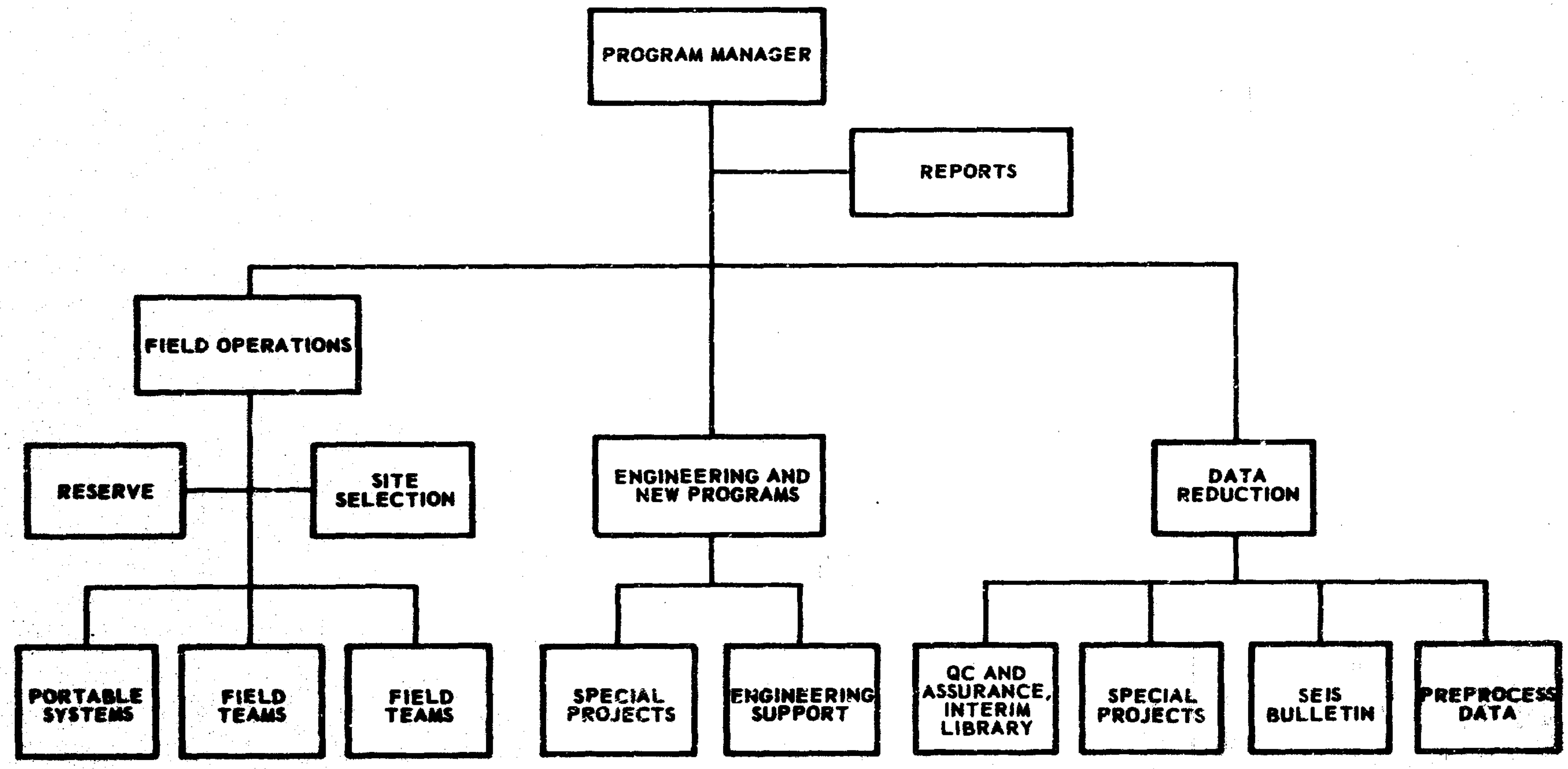

Figure 1. Organization of the LRSM program on 31 March 1966

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There have been no significant changes in the methods used for LRSM site selection. The portable systems operators generally select and permit the sites they occupy. Pertinent information for the LRSM Site Reports is submitted to the Site Selection Group, and that group prepares the reports. Site selection support for the mobile observatories continues to be provided by the geologists assigned to this task.

2.3 DATA PROCESSING

The processing and reproduction of magnetic-tape data into one of several visual formats is secondary in importance only to the recording of the data. The Special Presentations Group added several pieces of equipment to the magnetic-tape laboratory, thus expanding their capability to reproduce data in formats required for routine analysis and special studies.

A special oscillograph was assembled for recording portable system data on 35 mm film. The device utilizes up to eighteen 5 kc fluid-damped galvanometers, making it possible to record data played back from magnetic-tape at X1000 speed. The film is transported by a standard 35 mm continuous-strip oscilloscope camera.

Seismological bulletins containing representative data available from the LRSM stations continued to be published monthly. Data are processed from 10 stations each month. Shot reports for events selected by the Project Officer were prepared and distributed upon request.

2.4 EQUIPMENT MODIFICATIONS

Remote centering devices and remote free-period adjustment units were installed on the long-period seismometers. These modifications allow adjustments to be made on the seismometer without disturbing the thermal equilibrium of the instrument vault. Both the use of one-piece vaults and a current evaluation program on a new vault lid heater show promise for further reducing system noise on the long-period seismographs.

One experimental multiconductor cable system and one prototype lightning protection system were installed at separate LRSM stations. Both modifications have been successful in their intended purposes.

The supply motors on the tape transports were replaced with a viscous tape supply unit. The units have operated satisfactorily; however, a test program to determine the most satisfactory viscosity of the fluid used in the unit is currently underway.

Telemetry equipment was installed in the 2 observatories located in the LASA and in the 8 stations which formed the TFSO extended array. The modifications to these standard vans were extensive; for example, at LASA, 5 patch panels, 2 Develocorders, 40 data control modules, and operational amplifiers were among the equipment added to the mobile observatories. The LASA and the TFSO experiments have been concluded and these observatories have either been returned to their standard configurations or transferred from the LRSM program.

2.5 EQUIPMENT AND SEISMOGRAM EVALUATION

The emphasis placed on continually evaluating the field seismographs, and the records they produce, has been significant in solving problems with a minimum time loss. Our experience has shown that quality-control checks of the recorded data and a review of the results of these tests with the field operators are indispensible to the success of the field program. Each field team receives an average of four film and/or magnetic-tape critiques each month. The discrepancies noted on these critiques are eliminated through the joint efforts of the field teams and their supervisors. The most common problems encountered by the field teams have been: recording unusable station time on magnetic tape, excessive magnetic-tape system noise, and poor focus on the end of the 35 mm film strips. These and other minor problems are being investigated in hopes of finding workable solutions. Little loss of data is associated with these problems.

2.6 SPECIAL PROJECTS

The number and variety of specialized uses to which LRSM data can be applied have grown steadily. During this reporting period, the Special Projects Group has added to their capabilities in both personnel and experience. The programs conducted, which are discussed in this report, fall into the following general categories: surveys of seismological bulletin data; effects of site geology on signal and noise properties; and new data processing and calibration techniques.

3. FIELD OPERATIONS

3.1 GENERAL

The function of the LRSM mobile observatories is to record seismic signals from earthquakes and underground explosions for the VELA-Uniform program. In addition to this, the field teams have continued to be active participants in

a series of related programs and experiments. During the time period covered by this report, data were recorded and processed for two Plowshare experiments (SALMON and LONG SHOT) and operations support was extended to the following programs:

a.	VT/5051	- Development of a deep-hole seismograph
b.	LASA	- Subarray acquisition and land restoration program, shallow-hole seismograph and data evaluation, long-period seismograph evaluation
c.	USGS	- Crustal studies at the Tonto Forest Observatory
d.	USC&GS	- Seismogram analysis of data recorded at AD-IS and NP-NT
e.	LRL	- Operation of additional recording equipment in support of a special study
f.	Shell Development Corporation	- Deep-hole noise measurements program
g.	VT/4051	Conduct extended array telemetry program at TFO

The LRSM Field Operations Manual (TR 63-17) was revised to incorporate new concepts and techniques in field operations. When changes or modifications occur which materially affect the accuracy of the manual, changes are made simultaneously. Lesser manual changes are entered in a draft as they occur, and when these changes become numerous, the manual (or a section of the manual) is reprinted.

The most pertinent operational change which was made in this manual during the report period was in the calibration schedule for End of Month (EOM) and Pre-Critical Special Calibrations. The schedule change was made to assure at least a 50 percent recording capability during EOM calibrations by having half the stations calibrate on alternate consecutive days; that is, one-half on the last day of the month and one-half on the first day of the following month. The pre-critical special calibration schedule was altered so as to minimize outage time previously allocated for system calibration and necessary maintenance, and to assure either long-period or short-period capability on 35 mm or 16 mm film at all times.

All other operating schedules remained basically unchanged for all standard LRSM stations.

This section reviews the specialized and standard operations of all LRSM field teams during the report period. Figure 2 is a tabular summary of these activities. Figures 3 and 4 show the location of all 91 sites occupied by LRSM teams during July 1964 through March 1966.

3.2 SITE SELECTION ACTIVITIES

Three geologists are assigned to select the sites for the program. In this capacity, their duties range from map studies of potential locations to land restoration after site deactivation. In addition to landowner and power company negotiations, site selection field work includes land and noise surveys for array sites, preparation of shallow-hole and surface installations, installation assistance, and the collection of data for site reports. A total of 258 sites have been selected for the LRSM program. Thirty-nine sites were selected during the report period.

As in the past, distance and azimuth requirements continue to dominate site location considerations. Isolation from environmental effects, tempered by practical operational objectives, is the major task of the site selector. Tolerance limits of 30 to 40 kilometers from map locations allowed fair isolation of local noise in selecting the 19 new sites for the LONG SHOT event. Two geologists selected and permitted the station locations for this event, and furnished support to the site preparation teams.

There has been no appreciable change in the methods used for LRSM site selection. Usually, a tentative location is advanced by the client, available maps are gathered, and a geologist is sent to the field to select the site. Geographic coordinates for the station locations are taken from maps of the best scale and accuracy available.

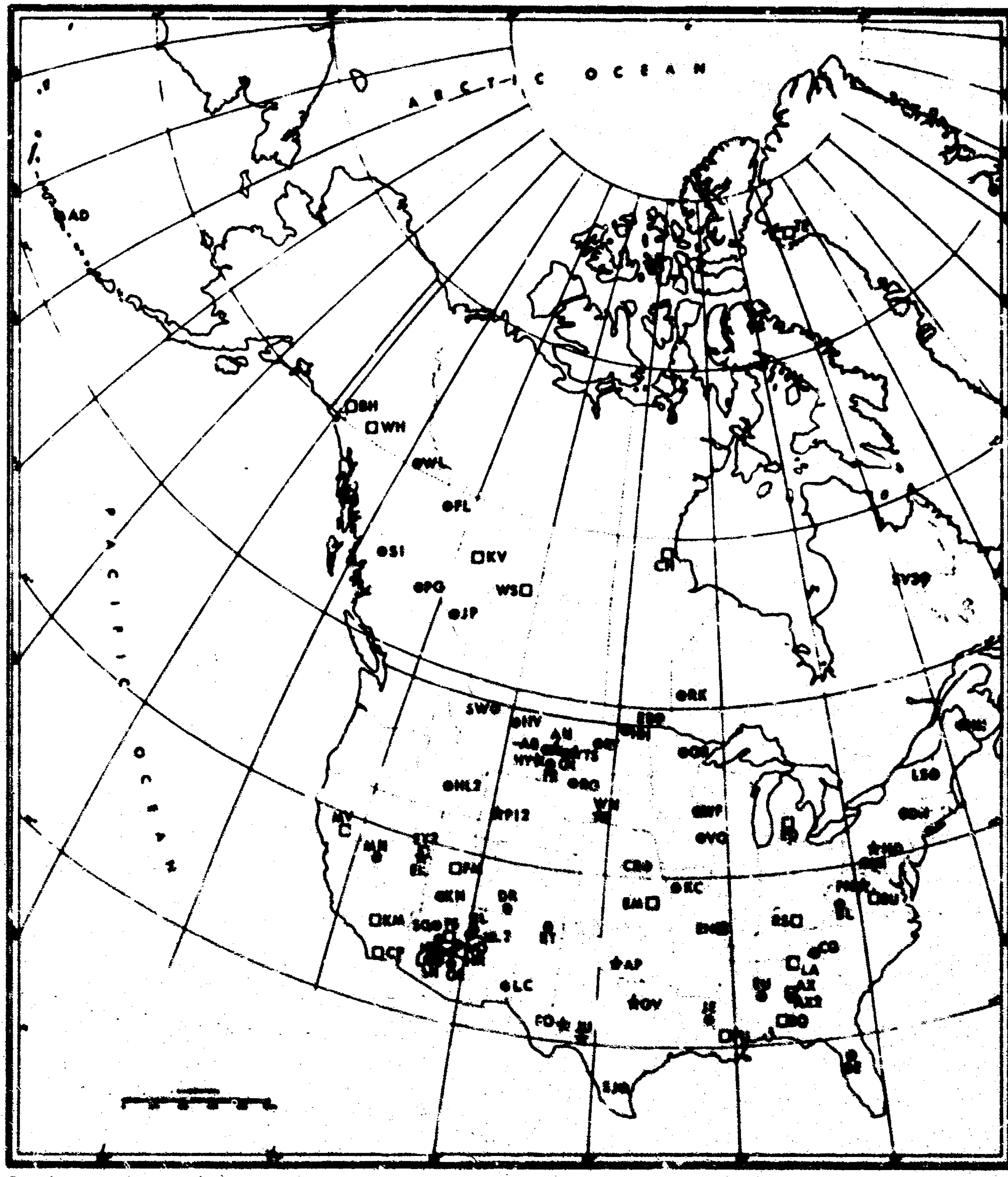
The operators of the portable seismograph system usually select, permit, and prepare their sites. This selection is coordinated with a geologist in the office who aids in location planning and prepares the site reports. If circumstances require additional support, a member of the site selection group will select the site in the field prior to the arrival of the portable equipment. This situation arose when sites were occupied in the eastern United States along an arc nearly equidistant from NTS for recording the CORDUROY event. Seismometer emplacement upon specific rock types was required for the study, and the schedule did not permit delays in site selection or system operation.

The portable seismograph system has increased the capability to obtain quiet site locations. This capability is not always fully realized, as the operator usually must select and permit a site and set up the system in a limited amount of time.

Type operation	Land miles traveled to occupy	Miles cable laid	Duration of recording period (in days)	No. of seismometer installations prepared	New sites selected	Total No. of sites occupied
Deep-Hole Seismograph Operations	8,710	28.8	2,399	6 shallow holes 22 tank vaults	5	12
Array Operations	2,219	44.0	2,327	16 tank vaults	1	8
Standard Van Operations	26,198	48.4	12,233	105 tank vaults	17	50
Portable Seismograph Operations	28,906	0.8	363	16 occurrences temporary shelters necessary	16	21
Totals	66,033	121.9	17,322	6 shallow holes 143 tank vaults 16 temporary shelter sites	39	91

NOTE: LRSM recordings contributed to the eastern Montana Large Aperture Seismic Array (LASA) at three sites. For this listing, AN-MA and HY-MA are considered deep-hole operations, and -A0MA is considered a standard van operation. Subarray data were recorded at all three of these LASA sites. Selection of the 21 LASA subarray sites and other LASA duties were also performed by Geotech on Project VT/4051.

Figure 2. LRSM field operations during July 1964 through March 1966



* STANDARD
□ PORTABLE
★ DEEP-HOLE

Figure 3. Location of LRSM sites occupied during the report period, 1 July 1964 through 31 March 1966

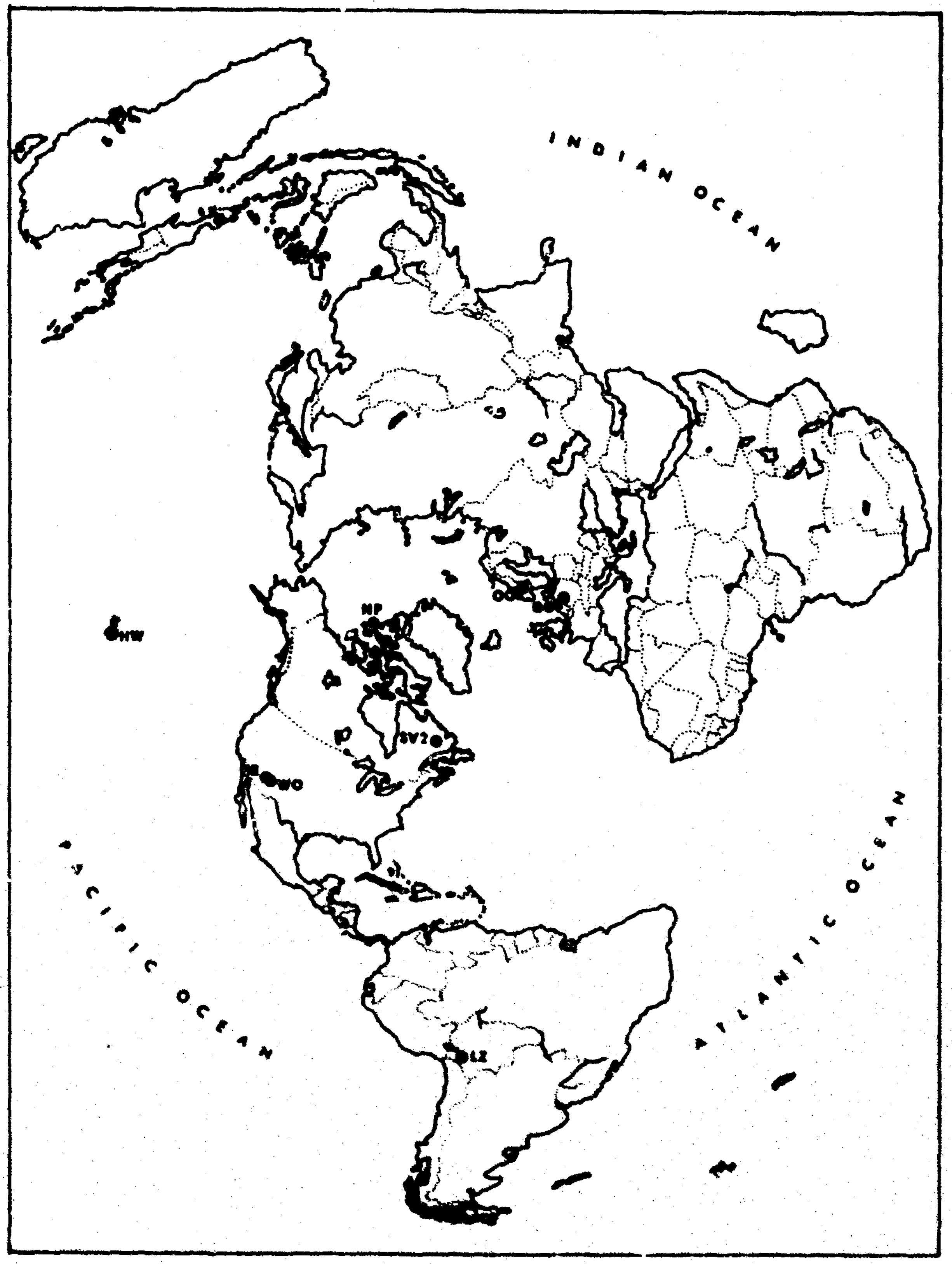


Figure 4. Location of array sites, 1 July 1964 through 31 March 1966

A notable accomplishment of the site selection personnel was the acquisition of the locations for the Large Aperture Seismic Array (LASA) in eastern Montana. The LASA covers a roughly circular area 238 km in diameter. Regional field reconnaissance preceded selection of the LASA subarrays. Aerial photographs, obtained from the United States Department of Agriculture, and noise surveys made with the Special Purpose Seismograph System, Model 15015, were two important factors contributing to the succeeding rapid selection of 21 subarrays of 25 shallow-hole locations each. LRSM vans occupied three of the subarray centers. Site selection activities ranged from selection of the individual subarrays to the settlement of landowner grievances after the array was put into operation. A land and fence restoration program was initiated. Field work covered the 12-month period of September 1964 to September 1965. The accumulation of land data obtained during that period is reported in TR 66-16, Large Aperture Seismic Array Surficial Information, Eastern Montana. TR 66-16 relates that from January through mid-July 1965, three field representatives were assigned to the LASA area to:

a. Finalize permitting and surveying operations;

b. Advise Teledyne Industries (prime contractor) on permit provisions, access, etc;

c. Obtain permit amendment executions requested by the Government;

d. Maintain contact with the landowners and settle grievances, so as not to retard installation progress.

3.3 OPERATION OF THE STANDARD OBSERVATORIES

Thirty-nine observatories were operational at the start of this report period. This total included:

26 Standard sites
7 Array sites
6 Deep-hole sites

During November 1964, a long-range program was initiated whereby several LRSM observatories would be transferred from VT/4051 to other organizations - both within and outside the VELA program. The United States Geological Survey (USGS) and the United States Air Force (USAF) were the first recipients of these seismological systems. During 1965, the USAF received additional observatories. Early in 1966, one system each was transferred to the Corps of Engineers and the Cambridge Research Laboratories, agencies of the USAF accepted five systems. On 1 July 1966, sixteen mobile observatories remained in service in the LRSM program. All but one

of these systems operated standard three-component short- and long-period seismographs. The observatory at Mould Bay, NWT, Canada (NP-NT) operates a seven-element crossed array of Johnson-Matheson short-period, vertical seismometers and a standard three-component long-period seismograph. Additional information on the operation of array and deep-hole seismographs is contained in following sections.

Standard observatories participated in the Tonto Forest Observatory Extended Array experiment. The array consisted of eight LRSM stations and TFSO. A telemetry network was installed which connected the mobile observatories to TFSO for the transmission of seismic data. The raw data was subsequently reduced and compiled through the joint efforts of VT/4051, TFSO, and the Massachusetts Institute of Technology, Lincoln Laboratory (VT/5055).

One standard LRSM station was equipped with an experimental multiconductor cable system. This cable system replaced the spiral-four cable and the Cook lightning protectors normally used for all data, calibration, and control circuitry external to the recording van. The purpose of this cable system is to (1) facilitate moving an LRSM station by reducing the time required to pick up, move, and set up at a new site; (2) reduce moisture and corrosion buildup on carbon blocks and cable connectors; (3) allow the line termination modules to be located inside the recording van for the operational convenience of the station personnel. Additional information pertaining to this cable system and other equipment modifications to observatory equipment is contained in sections 4 and 7.

Intrinsic environmental problems prevailed at all sites. Vault flooding was the most common of all problems. This was predominate at the northern sites where melting of extremely heavy winter snow in the spring of 1966 filled vault excavations with excess runoff. Although the problem of flooded vaults has not been completely eliminated, current site preparation methods and the use of epoxy and cement additives make the vaults virtually watertight. Water in the vault excavations has presented a problem to the long-period system since alternate thawing and freezing of water surrounding the vaults cause extreme temperature changes and tilting of the vault. All future installations will include drainage facilities where practical to ensure against excessive buildup of water in the vault area.

A total of 17 standard LRSM vans were relocated for Project LONG SHOT. It was determined that an average of 394 man-hours was required to set up a standard station. In several instances, extenuating circumstances (such as inclement weather conditions) delayed setup operations. The above average reflects the total number of hours expended.

3.4 OPERATION OF DEEP-HOLE SITES

The LRSM program provided six mobile observatories to support the operation of deep-hole seismographs. Three stations supported work under VT/5051; one van supported Shell Development Corporation in their noise measurements program, and two systems were operated within the LRSM program. As shown in figure 5, deep-hole operations continued during this report period until January 1966 at which time the final site was closed.

The instrumentation listed below was added to the six standard LRSM observatories to convert them for deep-hole operations:

a. Deep-Hole Seismometer, Model 11167;

b. Develocorder, Model 4000C;

c. Model 15769 deep-hole motor control unit;

d. Operational amplifiers;

e. Deep-hole ball-lift calibrators and ball-lift control unit;

f. Deep-hole electromagnetic calibrator and control unit;

g. Anemometer;

h. Additional PTA data control modules, and line termination modules;

i. Holelock;

j. Special instrumentation for recording at selected sites, such as coordinate transformers, special filters, triaxial seismometers and vertical arrays of seismometers.

The additional instrumentation at these stations presented a number of operational problems, the most prevalent being the Develocorder film processing system. Failures of the film drive system and stoppages of the chemical and water lines occurred frequently. These problems were never completely solved, but improved performance was gained by adhering to a rigid servicing and preventive maintenance schedule. Repeated seismometer failures were traced to bent delta rods, failures of the mass centering motors, and pressure case failures.

The administrative, as well as the operational work load was very heavy at the deep-hole sites. During routine recording periods, there were numerous

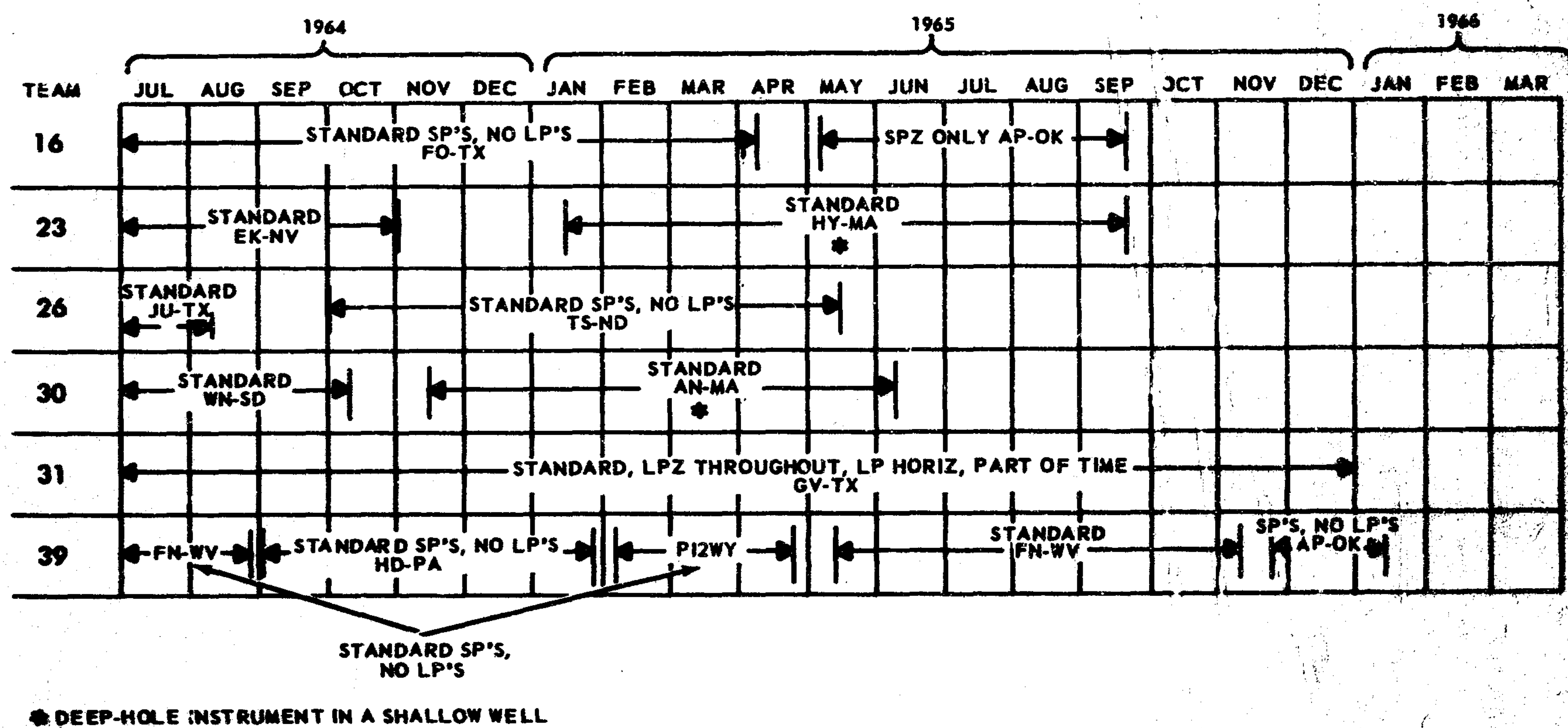


Figure 5. Deep-hole sites occupied

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reports, logs, and forms to complete. There were also special calibrations and tests at some stations which increased the work load.

A four-element array of vertical seismometers was operated at different times at the FN-WV site. The deep-hole site at GV-TX operated primarily as a test facility for developing and evaluating deep-hole devices. One such project was the testing of a six-element array of vertical seismometers. Tests were also conducted with triaxial seismometers, coordinate transformers, and special filters and amplifiers.

The average setup time for deep-hole and standard three-component short-period surface instrumentation was 446 man-hours. The long-period systems usually were installed after the stations became operational. An estimated average of 210 man-hours was required to set up the long-period systems.

3.5 OPERATION OF PORTABLE SYSTEMS

Six portable seismograph systems have been in operation since October 1965. Figure 6 shows the 21 sites occupied by the portable seismographs since their addition to the LRSM program. The average time required for setup and complete calibration of the three-component short-period instrumentation has been 16 man-hours. The long-period seismographs are usually installed after the short-period system becomes operational. An average of 56 man-hours was required to set up the long-period systems. It should be noted, however, that the setup and operation of the three-component short-period seismographs can be accomplished within approximately 3 hours if the requirements are such that this is necessary. Calibration of the seismometers and the recording systems can be accomplished at a later date.

The most significant problems associated with the operation of the portable systems have been:

a. Power source failure - Operational problems have been encountered with the portable system power battery pack that furnishes the primary system power in the field. The battery pack consists of eight silver-zinc cells. On two occasions, a complete battery pack was destroyed while being charged unattended. There have been several instances of individual cells shorting internally and causing overcharging of all eight cells within the battery pack. The damaged cells have been returned to the manufacturer where efforts are being made to determine the exact cause of failure. A pronounced deterioration has been noted in the cell life of the silver-zinc batteries after 10 months of active use. The problems with the present power source have resulted in a recommendation to replace the silver-zinc cells with silver-cadmium cells which are expected to increase the life of the power source by a factor of 3.

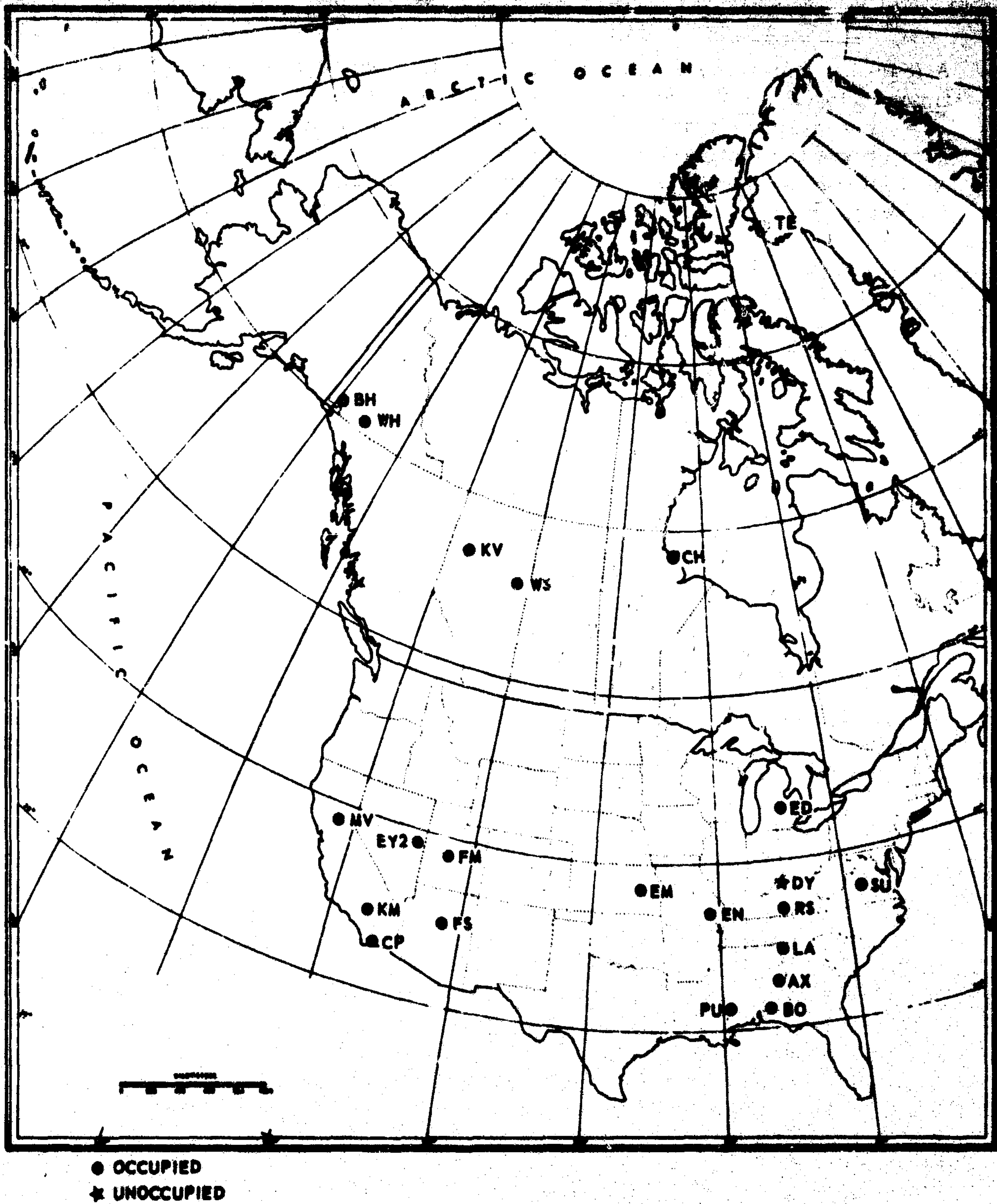

Figure 6. Location of portable system sites, 1 July 1964 through 31 March 1966

b. Heater failure - Problems have occurred during operations in the field with the portable system heater. Heat is supplied to the system when necessary (ambient temperatures below 30°F) by a propane jet heater mounted on the wall of the portable shelter. Under operational conditions, moderate winds extinguish the heater flame. The resultant loss of heat causes irregular operation, and in some instances temporary failure, of the timing system. Loss of heat also causes irregularities in the operation of the magnetic-tape system and the photocell amplifiers. Action is being taken to correct this problem.

c. Photocell amplifier galvanometer offsets - The dc balance and galvanometer centering adjustments are very sensitive and difficult to perform. Galvanometer drift is common, but rarely interferes with the record quality or the recorded dynamic range.

d. Helicorder component failures - Several minor problems have been encountered with the Helicorder components, the most common being pen heat circuitry, frequent fuse replacement, and irregularities in the tape calibrator and playback amplifier. The majority of these problems involve only replacement of minor components as a normal service procedure.

e. Operational considerations - Portable systems teams are much more vulnerable to poor weather conditions than are the mobile observatories. Tight travel schedules and short-term operating requirements are generally a part of the operation plan. If inclement weather prevents the occupancy of a preselected site for even 1 day, an alternate location must be found quickly, or the purpose of the mission may be lost. The selection of alternate locations, while often necessary, may lessen the value of the data recorded. This is particularly true when data is required from a previously occupied site.

Additional setup time is required when the systems' operators are required to select and permit the sites they occupy. Often, the time required to perform this task is not available without authorizing considerable overtime.

The contract vehicles assigned to the portable systems are now 5 years old. Even though they are maintained between trips, frequent and costly repairs are often required enroute to site locations. Air freight provides a generally reliable and rapid source of transportation to metropolitan areas, but rental vehicles are required at the off-loading point. Some damage to the systems components due to mishandling must be expected when the equipment is shipped by a commercial carrier.

3.6 OPERATION OF ARRAY SITES

On 1 July 1964, five LRSM observatories were operating arrays, all at overseas locations. One additional array in Canada and two arrays in Arizona

were installed during the report period. The following is a tabular summary of the array configuration at the eight array stations and their current status:

Station	Array configuration	Other systems	Site status
GG-GR	7-element crossed	Standard SP & LP	Transferred to OSR 2 Mar 65
HW-IS	15-element crossed	Standard SP & LP	Transferred to USGS 9 Jan 65
LZ-BV	7-element crossed	Standard SP & LP	Transferred to OSR 15 Feb 65
OO-NW	7-element crossed	Standard SP & LP	Transferred to OSR 1 Apr 65
NP-NT	7-element crossed	Standard SP & LP	Operational
SV2QB	3-element linear	Standard LP	Installed 20 Sep 64 Closed 23 July 65
JR-AZ	7-element hexagonal	Standard SP & LP	Installed 19 Jan 65 Closed 4 Oct 65
WO-AZ	7-element hexagonal	Standard SP & LP	Installed 17 Jan 65 Closed 4 Oct 65

No new instrumentation or systems modifications were required for the overseas arrays. The JR-AZ and WO-AZ stations were operated as subarray stations in the Tonto Forest Observatory Extended Array experiment. The following instrumentation was installed in these LRSM observatories for additional recording capability, signal isolation, array calibration, and telemetry:

a. One additional 35 mm film recorder

b. Frequency meter

c. Rack adapter and VCO's

d. VCO gain control

e. VCO control unit

f. VCO calibrator

g. Modulation equipment

h. Summation control unit

i. Operational amplifiers for isolation and summation

j. Seismometer calibration line selector

k. Extra data control modules

l. Dual chimney blower for telemetry equipment

m. Line driving amplifier

Special tests were performed throughout the period of operation at the Jerome and Winslow arrays. These tests, which required frequent changes in calibration procedures, were conducted for a study of possible methods of determination of system response by signal analysis rather than calibrations. No unusual instrumentation problems were encountered.

The Schefferville array was operational from 25 September 1964 to 23 July 1965. Extreme cold weather conditions hindered station operations throughout the winter months.

The average setup time for the short-period instrumentation at the Schefferville, Winslow, and Jerome arrays was 940 man-hours. The long-period seismographs were operational at the beginning of the report period at Winslow and Jerome. The installation of the long-period seismographs at Schefferville took approximately 390 man-hours.

4. EVALUATION OF STANDARD AND MODIFIED INSTRUMENTATION

4.1 GENERAL

The following discussion is an evaluation of major equipment within the LRSM seismograph system, and is devoted primarily to the instrumentation used in the standard LRSM mobile van. An evaluation of some nonstandard instrumentation such as array instruments, telemetry equipment, and special seismometer and amplifier tests has also been included. Modifications performed on the instrumentation during this report period are discussed in section 7.

4.2 SEISMOMETERS

4.2.1 Benioff Vertical Seismometer, Model 1051, and Benioff Horizontal Seismometer, Model 1101

The large Benioff seismometers continue to operate with little or no maintenance. Extreme environmental conditions which promote condensation, fungus growth, and oxidation have caused some difficulty as these units are not sealed; however, these problems are infrequent, and instrument reliability has been proven in field applications.

4.2.2 Portable Vertical Variable-Reluctance Seismometer, Model 4681A, and Portable Horizontal Variable-Reluctance Seismometer, Model 6102A

The portable Benioff seismometers have performed with a high level of reliability. These seismometers are preferred by operators over the large Benioff sensors because of their relatively light weight and portability.

4.2.3 Portable Short-Period Seismometer, Model 18300

These portable seismometers are presently used as the detectors in the portable seismograph system. They can be quickly and easily converted from vertical to horizontal operation by detaching the cantilever spring suspension. They can be buried directly in the ground without special containers and are about one-half the size and weight of the portable Benioff seismometer. Some delta rod failures have occurred because of abuse during shipping. Field experience with these seismometers has proven them to be very reliable instruments.

4.2.4 Long-Period Sprengnether Seismometers

The most predominant problems associated with the operation of the Sprengnether long-period seismometers continue to be associated with the environment in which they are operated. A mass position indicator mechanism of improved design was installed on all long-period seismometers. These units provide a more reliable indication of seismometer mass position. The addition of remote free period and remote mass centering devices makes possible a more precise adjustment of the position of the seismometer pendulum and the seismometer natural period. Failure of the suspension system due to rusted hinges has been an infrequent problem. Field team operators have been instructed to routinely inspect and replace suspect hinges.

4.2.5 Vertical Long-Period Seismometer, Model 7505A, and Horizontal Long-Period Seismometer, Model 8700C

Geotech Model 7505A and Model 8700C long-period seismometers are employed in the portable seismograph system. These units are equipped with remotely operated mass position and free-period adjustment mechanisms. These detectors are not well suited for portable applications because of their weight (91 kg). Installation of these seismometers is accomplished more easily than the Sprengnether sensors because they are shipped completely assembled, with only the inertial mass removed. Suspension damage, caused by rough handling in shipment, and the loss of the magnet field strength have been the most common problems encountered.

4.2.6 Johnson-Matheson Vertical Seismometer, Model 6480

The Johnson-Matheson seismometers, in operation at La Paz, Bolivia and Mould Bay, Canada, continue to operate satisfactorily. The extreme temperature fluctuations at Mould Bay (NP-NT) have required considerable preventive maintenance in the form of mass centering adjustments on the seismometers in order to maintain operations.

New Calibration Actuator Kits, Model 18351, were installed on these seismometers during this report period and have provided reliable calibrations. Translational-mass type weight-lift calibrators were also designed and installed on the Johnson-Matheson seismometers. They have operated satisfactorily.

4.2.7 Long-Period Seismograph Tests at LASA Subarray F3

In May 1965, tests were begun to develop techniques for improved long-period seismograph installations in LASA. The details of these tests are reported in Technical Report No. 65-47.

This experimental program was conducted at LASA subarray F3 (Hysham, Montana) to develop a reliable, unmanned, seismograph system capable of producing high-quality long-period seismograms. An underground, monolithic concrete bunker was constructed and fitted with 1 floor-coupled and 2 isolated-tank vaults as shown in figure 7. One Model 7505A seismometer and two Model 8700C seismometers were installed in these vaults. A block diagram of the test system is shown in figure 8.

Results of the tests indicated that a 15-20 second period seismic noise limited the magnification of the vertical seismograph to approximately 60K. Higher amplitude noise peaking at 30-40 seconds restricted the horizontal seismographs to a magnification of 20-25K.

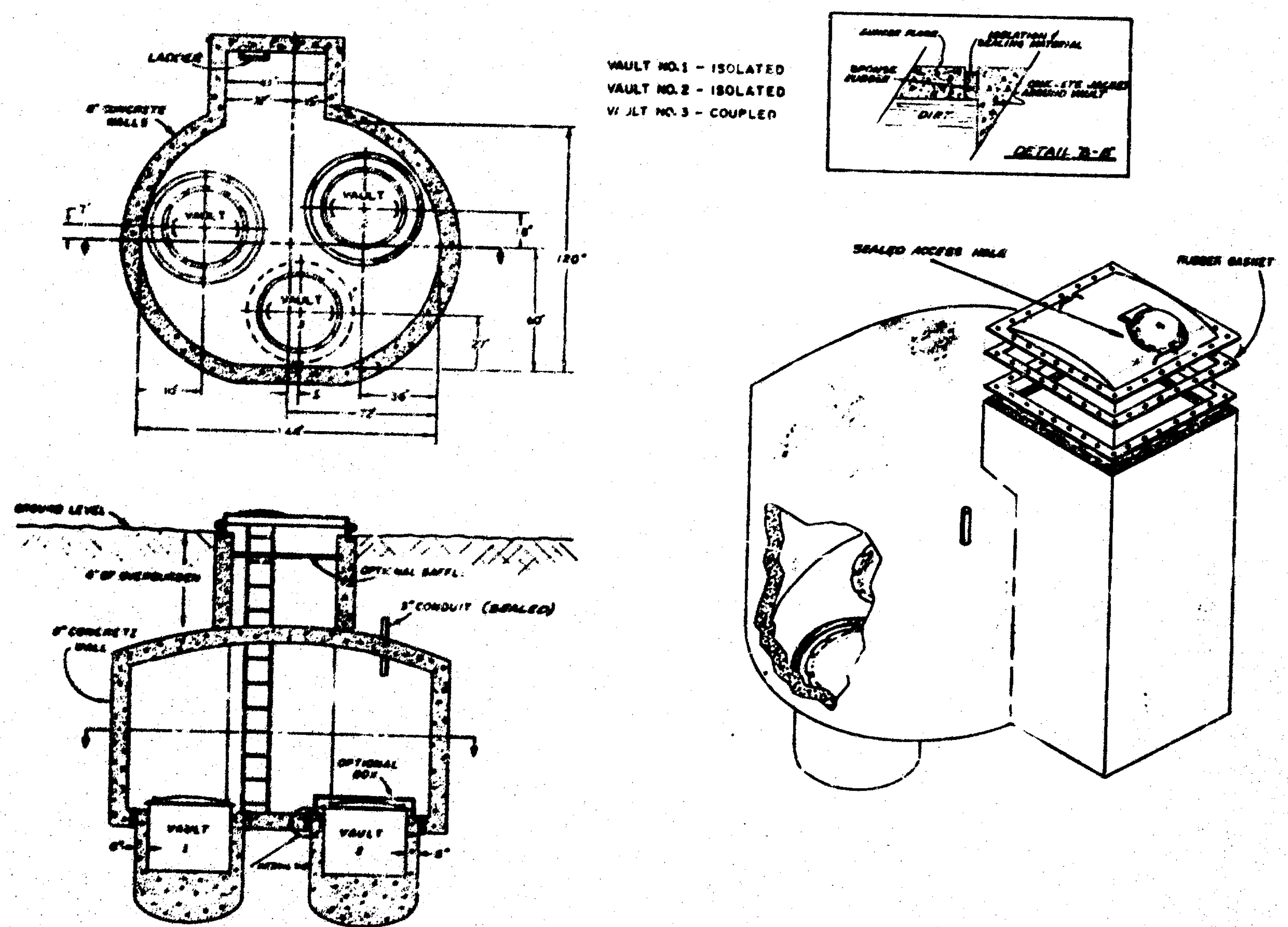

Figure 7. Bunker for LASA long-period seismometer experiments

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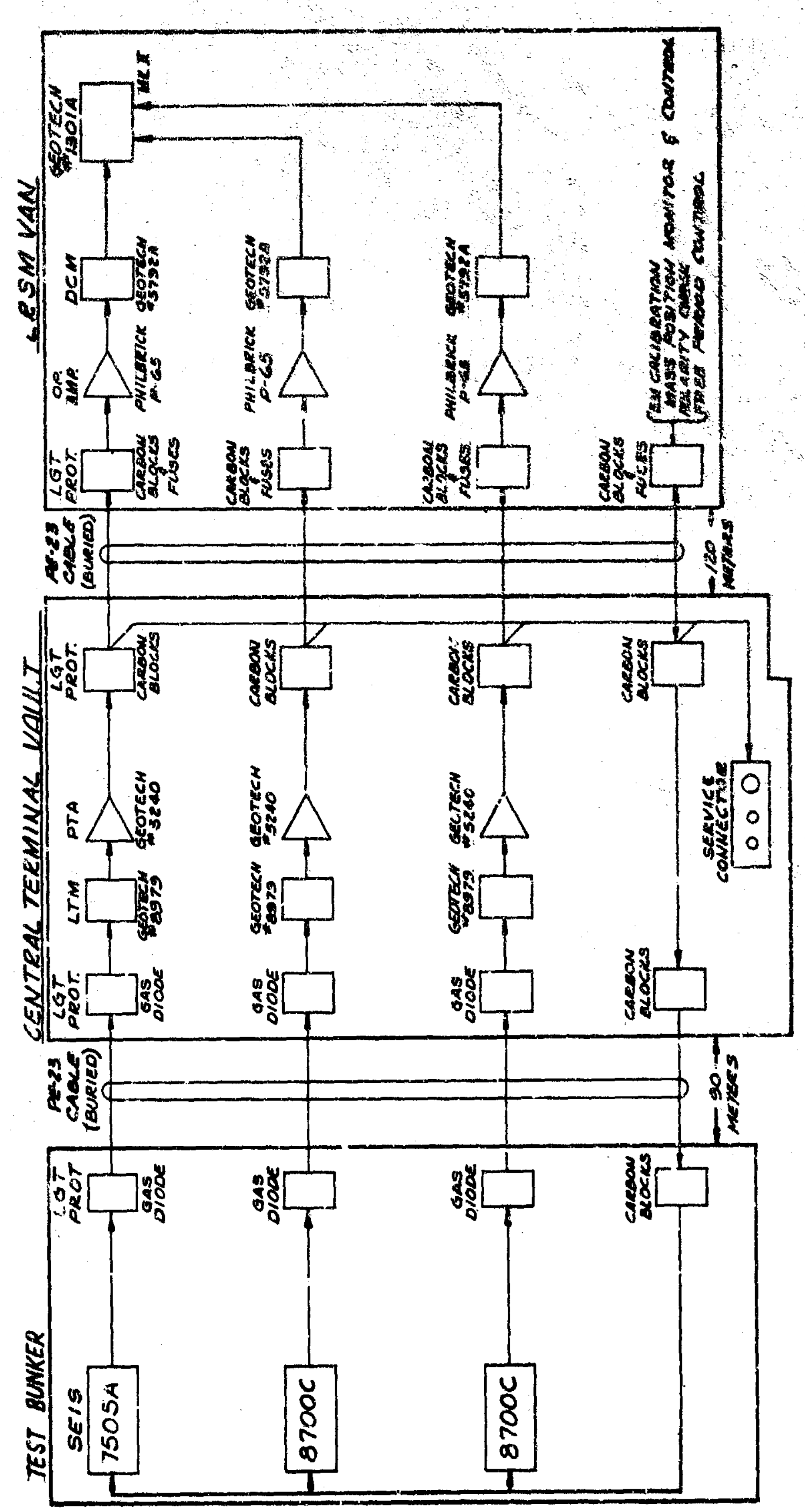

Figure 8. Experimental long-period system for LASA, block diagram

4.3 AMPLIFIERS

4.3.1 Phototube Amplifier, Model 4300

No major problems have been encountered in the operation of the short-period phototube amplifiers. Failures of electronic tubes, galvanometers, and phototubes occur infrequently and are easily detected and corrected.

4.3.2 Long-Period Phototube Amplifier, Model 5240

The long-period phototube amplifiers have operated reliably. The occasional failures associated with the Model 4300 amplifiers also apply to this unit. The long-period characteristic of this instrument makes it somewhat difficult to maintain proper dc balance and galvanometer centering. To improve the dc balance adjustment, the single turn dc balance potentiometers in the power supply were replaced by 10-turn precision wire-wound potentiometers. This modification has proven successful in reducing both the time required to make the adjustment, as well as the level of the dc unbalance of the units.

4.3.3 Amplifier and Control Unit, Model 23927 and Amplifier and Control Unit, Model 23928

The Model 23927 short-period amplifier and control units and the Model 23928 long-period units are used in the portable seismograph system. They can be easily transported because their rugged galvanometer suspension resists damage from shock and vibration. The dc balance and galvanometer centering adjustments are very sensitive and difficult to perform. The most common problem associated with these instruments is galvanometer drift; however, this drift seldom interferes with the maximum dynamic range of the recordings. The following problems have also been experienced:

a. The oscillator in the dc converter is difficult to start, especially in cold weather.

b. Wires in the internal wiring harness are easily broken during troubleshooting.

4.3.4 Electro-Tech Amplifier, Model SPA-10-1

An evaluation program was conducted on the Mandrel Industries' Amplifier, Model SPA-10-1 (shown in figure 9) to evaluate it for use in the portable seismograph system. Details of these tests are reported in Technical Report No. 66-41. In summary, the unit is constructed for general field use. Modular packaging is employed in the printed circuit construction of this amplifier. The SPA-10 is a version of the SPA-1 unit that has been modified to extend the low-frequency response from 0.5 cps to 0.1 cps. Self-contained rechargeable nickel-cadmium batteries or an external power source may be used.

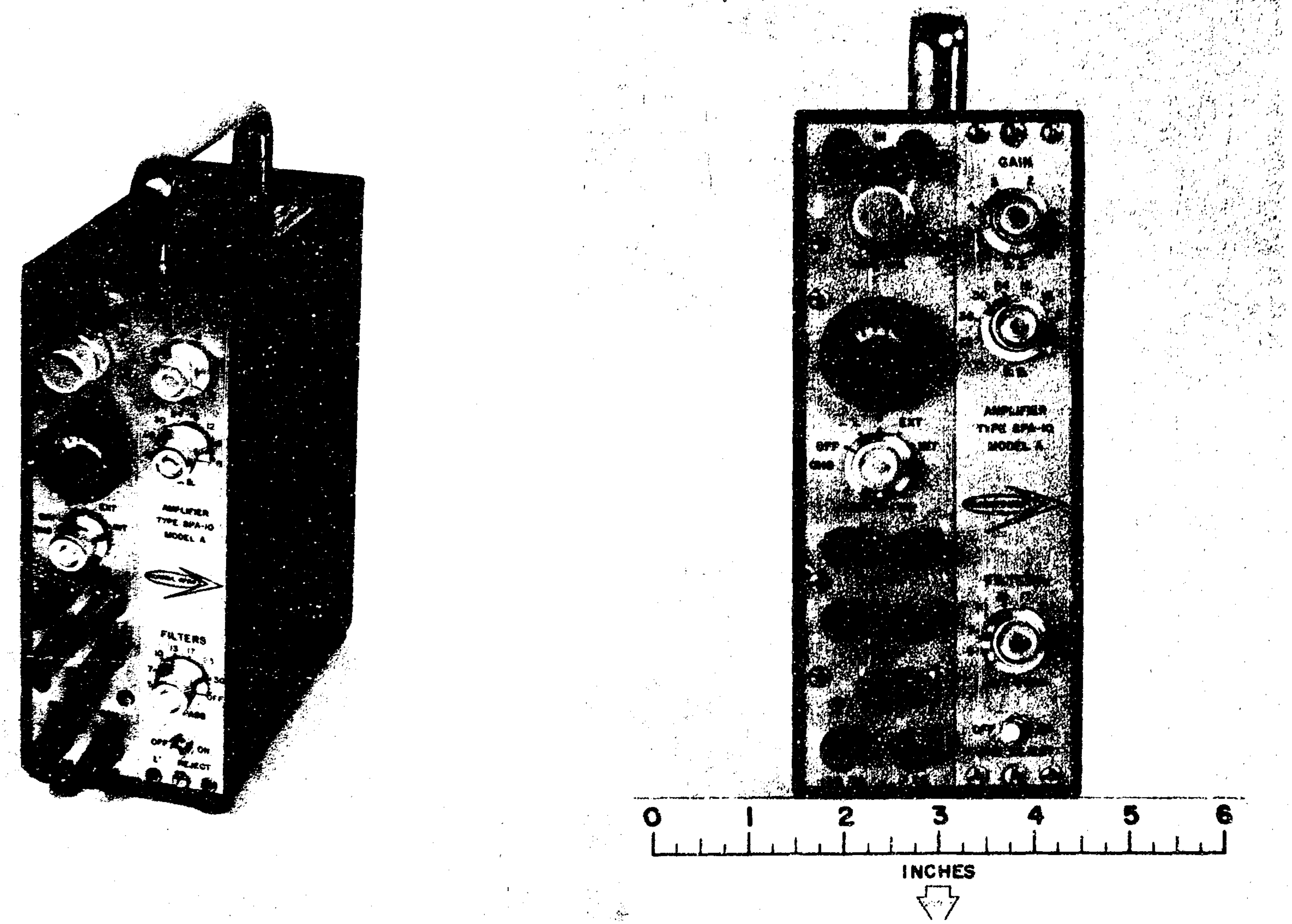

Figure 9. SPA-10-1 single-channel amplifier system

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The results of the evaluation indicate that the poor temperature characteristics and relatively high noise level of this amplifier make it unsuitable for use in the portable seismograph system.

4.3.5 Evaluation of Low-Frequency Amplifiers and Short-Period Seismometers

An evaluation program was conducted in an effort to provide comparative test data on a number of amplifiers, seismometers, and amplifier-seismometer combinations for use in short-period seismographs. The entire program was reported in Technical Report No. 65-69. The instruments evaluated in this study include some experimental and prototype models as well as production units from various manufacturers.

Each amplifier included in the study was submitted to the same basic tests. The seismometers which were evaluated were subjected to a series of shake-table tests and environmental tests in the laboratory. Several combinations of amplifiers and seismometers were operated in the field. Seismic data were recorded and the recorded data from each test seismograph were compared to the same data recorded by a surface seismograph composed of a Short-Period Vertical Johnson-Matheson Seismometer, Model 6480, and a Phototube Amplifier, Model 4300. The characteristics of the various seismometer and amplifier combinations operating in the best configuration are shown in table 1.

4.4 DATA LINES

4.4.1 Spiral-Four Cable

This four-conductor cable continues to perform satisfactorily as a field cable. Moisture penetration into the connectors has caused minor difficulty.

During this report period, tests were conducted to determine the transmission characteristics of spiral-four cable. The results of these tests are reported in Technical Report No. 65-63. Two general experiments were conducted. The first dealt with measuring voltage amplitudes as a function of cable length, conductor arrangement, and signal frequency. This study demonstrated that within the signal frequency range of 500 cps to 5000 cps, the response of the spiral-four cable is a significant function of signal frequency and can be the limiting factor in the quality of a transmission link.

The second series of experiments defined the loading techniques required for this cable to provide a frequency response below 10,000 cps that is essentially independent of frequency.

Table 1. Characteristics of various seismometer and amplifier combinations

Seismometer	Amplifier	Detection threshold (mu, p-p) @1.0 Hz [1]	Seismograph bandpass (Hz) [2]	Seismograph dynamic range (dB)	Seismograph output sensitivity (e_o) (mv/mμ)	Provisions for 5.0 Hz filter in amplifier	Amplifier terminal impedance (ohms)	Seismometer coil resistance (R_c) (ohms)	Seismometer generator constant (G) (volt-sec/m)	Seismometer natural period (sec)
HS10-1/ARPA	RA-3	0.135	0.01-5	73.6	7.8	None	56,000	77,000.0	878.0	1.0
	2100C	0.94	0.01-5	86.0	1.85	None	4,000	[illegible]	404.0	1.0
	3000X	3.33 [3]	0.05-5	47.3	3.3	None	5,000	5,720.0	[illegible]	1.0
	120	0.122	0.01-5	24.5	1,800.0	None	4,000	4,500.0	404.0	1.0
	EA 210	1.51	0.01-5	25.1	740.0	Yes	4,000	4,300.0	454.0	1.0
	GA 230	0.405	0.01-5	66.2	21.6	Yes	66	33.0	38.2	1.0
	4300	0.14	0.01-5	78.0	14.3	Yes(input)	40	19.5	38.0	1.0
	12613-1	0.422	0.01-5	55.1	49.6	Yes(input)	40	19.5	20.0	1.0
	59D	8.7	0.3-5	10.8	180.0	Yes	4,000	4,500.0	424.0	1.0
	TA-L	60.0	0.3-5	0	251.0	Yes	200	230.0	[illegible]	1.0
	SIE	205.0	0.5-5	8.9	3.96	None	220	232.0	97.5	1.0
	T6823C	1.14	0.01-5	70.7	0.14	None	5,000	5,810.0	488.6	1.0
	16957	1.32	0.01-5	54.0	22.8	Yes	5,000	5,720.0	404.0	1.0
	A20-1	0.87	0.01-5	82.9	2.07	None	5,000	5,720.0	404.0	1.0
Willmore Mk II	RA-3	0.0436	0.01-5	73.6	29.0	None	56,000	78.9K	[illegible]	1.0
	2100C	0.368	0.01-5	86.0	1.36	None	4,000	6.3K	872.0	1.0
	3000X	2.27	0.05-5	47.3	7.6	None	5,000	7.85K	973.0	1.0
	120	0.22	0.01-5	24.5	2,730.0	None	4,000	6.3K	872.0	1.0
	EA 210	1.03	0.01-5	25.1	1,080.0	Yes	4,000	6.3K	873.0	1.0
	GA 230	0.106	0.01-5	65.2	82.5	Yes	65	63.6	86.0	1.0
	4300	0.0487	0.01-5	78.0	41.0	Yes(input)	40	88.2	[illegible]	1.0
	12613-1	0.166	0.01-5	55.1	144.0	Yes(input)	40	90.2	[illegible]	1.0
	59D	6.9	0.3-5	10.8	266.0	Yes	4,000	6.3K	873.0	1.0
	TA-L	27.9	0.3-5	0	360.0	Yes	200	314.0	199.0	1.0
	SIE	82.5	0.5-5	8.9	9.85	None	220	915.0	332.0	1.0
	T6823C	0.78	0.01-5	70.7	0.268	None	5,000	7,950.0	900.0	1.0
	16957	0.96	0.01-5	54.0	60.0	Yes	5,000	7.85K	973.0	1.0
	A20-1	0.592	0.01-5	82.9	3.04	None	5,000	7.85K	975.0	1.0
18300	RA3	0.047	0.01-5	73.6	26.8	None	56,000	79.6K	2,900.0	1.3
	2100C	0.400	0.01-5	86.0	2.5	None	4,000	6.37K	810.0	1.0
	3000X	2.48	0.05-5	47.3	6.95	None	5,000	7.95K	985.0	1.0
	120	0.240	0.01-5	24.5	2,500.0	None	4,000	6.37K	810.0	1.0
	EA 210	1.12	0.01-5	25.1	1,000.0	Yes	4,000	6.37K	810.0	1.0
	GA 230	0.142	0.01-5	68.2	61.5	Yes	68	128.4	101.0	1.0
	4300	0.0815	0.01-5	78.0	38.8	Yes(input)	40	100.2	79.2	1.0
	12613-1	0.1545	0.01-5	55.1	136.0	Yes(input)	40	100.2	79.2	1.0
	59D	6.44	0.3-5	10.8	242.0	Yes	4,000	6.37K	810.0	1.0
	TA-L	30.9	0.3-5	0	325.0	Yes	200	319.0	183.0	1.0
	SIE	87.2	0.5-5	8.9	9.32	None	220	[illegible]	317.0	1.0
	T6823C	8.86	0.01-5	70.7	0.19	None	5,000	8,100.0	982.0	1.0
	16957	9.98	0.01-5	54.0	30.7	Yes	5,000	7.95K	992.0	1.0
	A20-1	0.647	0.01-5	82.9	2.78	None	5,000	7.95K	988.0	1.0
20171	RA-3	0.098	0.01-5	73.6	13.2	None	56,000	107,000.0	3,150.0	1.0
	2100C	0.794	0.01-5	86.0	1.26	None	4,000	14,000.0	900.0	1.0
	3000X	4.93	0.05-5	47.3	3.5	None	5,000	17,500.0	1,007.0	1.0
	120	0.476	0.01-5	24.5	1,260.0	None	4,000	14,000.0	900.0	1.6
	EA 210	2.22	0.01-5	25.1	503.0	Yes	4,000	14,000.0	900.0	1.0
	GA 230	0.179	0.01-5	66.2	49.0	Yes	65	171.0	188.0	1.0
	4300	0.068	0.01-5	78.0	30.8	Yes(input)	40	106.0	82.6	1.0
	12613	0.196	0.01-5	55.1	107.0	Yes(input)	40	106.0	82.6	1.0
	59D	12.8	0.3-5	10.3	122.0	Yes	4,000	14,000.0	900.0	1.0
	TA-L	50.5	0.3-5	0	199.0	Yes	200	528.0	185.0	1.0
	SIE	110.0	0.5-5	8.9	7.38	None	1,600	2,830.0	486.0	1.0
	T6823C	1.36	0.01-5	70.7	0.118	None	5,000	13,400.0	943.0	1.0
	16957	1.94	0.01-5	54.0	15.5	Yes	5,000	17,500.0	1,007.0	1.0
	A20-1	1.28	0.01-5	82.9	1.41	None	5,000	17,500.0	1,007.0	1.0
EV-21V	RA-3	0.0765	0.01-5	73.6	15.8	None	50,600	50,600.0	1,120.0	1.0

(1) Threshold is defined as the ground motion required to produce an output voltage from the seismometer transducer which is equal to the input noise level of the amplifier when the amplifier input is terminated with the transducer impedance. (Based on peak-to-peak noise voltage measurements and peak-to-peak ground motion).

(2) A high-frequency cutoff of 5.0 Hz was used for all measurements and calculations. The basic amplifier cutoff frequencies met or exceeded this value in every case.

(3) This threshold figure reflects a noise measurement which included random impulses. The figure listed for the Model 2100C amplifier does not include these impulses although they were observed.

4.4.2 Multiconductor Cable System

An experimental multiconductor cable system was designed to replace the spiral-four cable and the Cook lightning protectors normally used for all data, calibration, and control circuitry external to a recording van. The purpose of the system was:

a. To facilitate moving an LRSM station by reducing the time required to pick up, move, and set up at a new location;

b. To reduce moisture and corrosion buildup on carbon blocks and cable connectors;

c. To allow the line termination modules to be located inside the recording van for operational convenience to the station personnel.

A cable system of this type was installed and evaluated at the SN-AZ site in Arizona. The performance of this team during a move from the SN-AZ site in Arizona to the JP-AT site in Alberta, Canada, demonstrated the increased mobility and the savings in man-hours provided by this modification.

Figure 10 shows this cable modification installed at the SN-AZ site.

The cable used in this system is a 20-conductor, armored, and shielded cable. Figure 11 shows the main features of the cable. The use of sealed connectors on the cable and the protector boxes eliminates the need to strip the cables and to prepare connections at the protectors. This modification provides the following improvements and cost savings:

a. The time required to complete the installation of a standard LRSM station will be reduced by approximately 10 man-days due to the reduced number of cables to be installed and the reduced number of connections to be made.

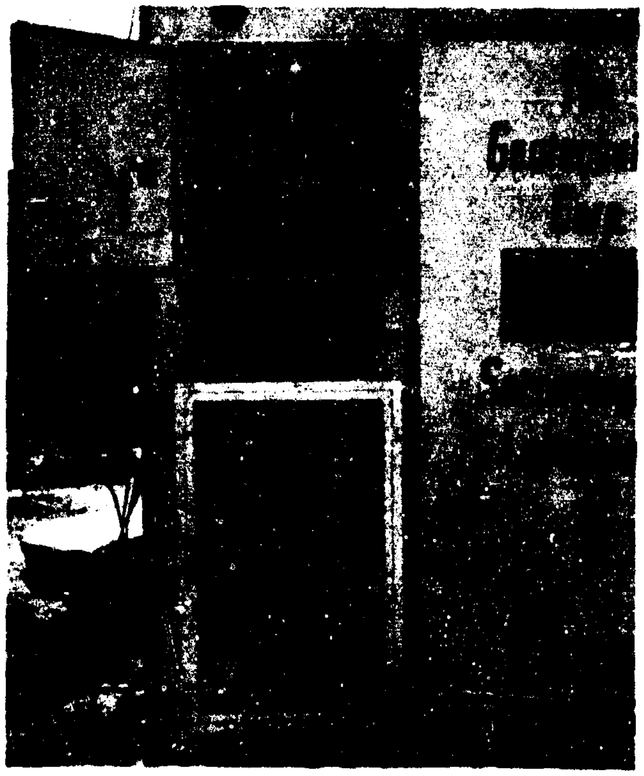
b. The time required to pick up a standard LRSM station will be reduced by approximately 4 man-days.

c. Noise problems relating to moisture and corrosion in the carbon block protectors in the lightning protection circuitry will be eliminated.

4.4.3 Belden Foil Shield Two-Conductor Cable (LASA)

Belden 8451 Belfoil Miniature Broadcast cable was selected for installation in the LRSM mobile observatories assigned to LASA.

This cable was selected on the following basis: (a) nominal outside diameter of 0.135 inch requiring 1/2 to 1/3 less space than would normally be required



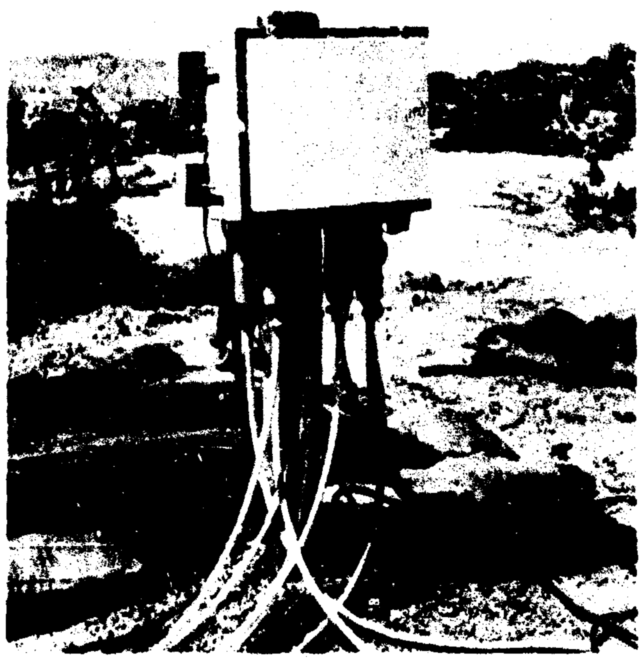


Figure 10. Two views of the 20-conductor cable installed at SN-AZ

G 1730

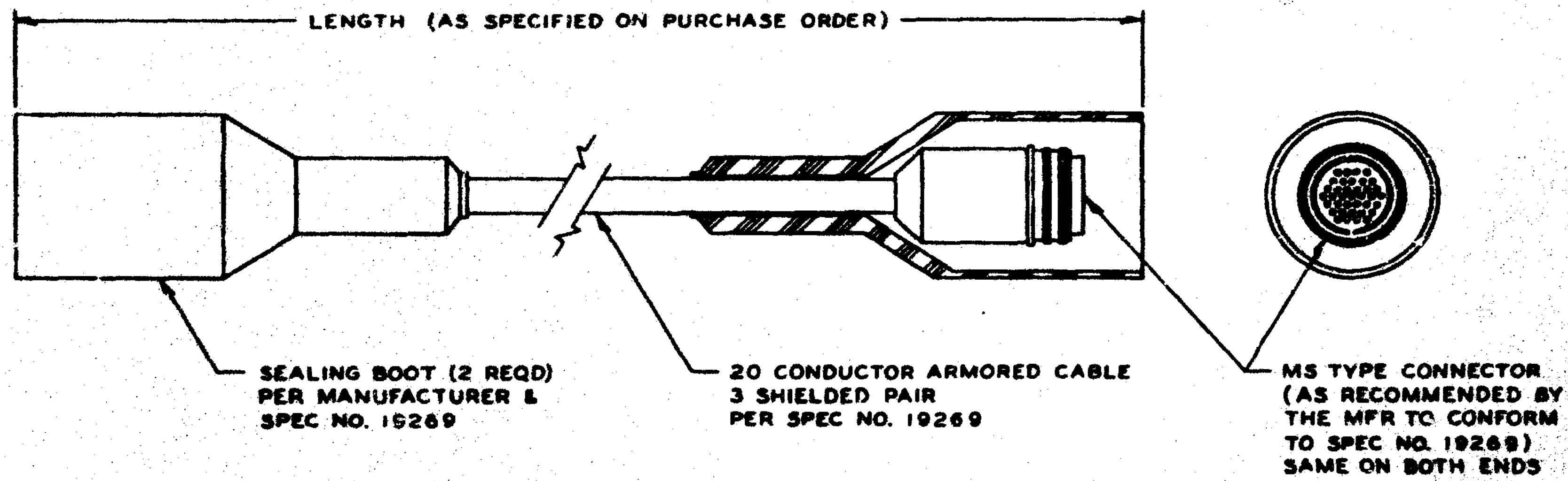


Figure 11. Field cable, 20-conductor

G 1731

for a similar installation using Belden 8422 cable; (b) comparatively rugged construction of stranded tinned copper conductors and Polypropylene insulation; and (c) 100 percent shield coverage with an aluminum-coated Mylar wrap shield.

4.5 LIGHTNING PROTECTION

4.5.1 Carbon Block and Fuse Protection

All but two of the LRSM mobile seismograph stations continue to operate with fuses and carbon blocks (Cook 09 protectors) for lightning protection on field circuits. This lightning protection is adequate for most thunderstorms; however, it will not protect against severe lightning discharges near the equipment or cabling. The most significant problem associated with the operation of these protectors is the accumulation of dirt, or carbon buildup in the arc gap of the carbon blocks. This buildup produces a low resistance to ground and causes crosstalk, loss of signal, ac ground loops, and other problems which are time consuming to eliminate. The Cook protectors have also been determined to be a source of thermal noise in long-period circuits.

4.5.2 Gas-Diode Lightning Protection

A new lightning protection unit, employing gas-filled diodes, has been designed for the mobile observatories. This modification eliminates the use of the Cook type carbon blocks and fuses. The most significant feature of this lightning protection circuitry is the application of the AEI, Model 54A, gas diodes, which replace the conventional carbon blocks. These diodes discharge at 150 volts versus 600 volts for the carbon block type protectors. In addition, both sides of a circuit pair are grounded simultaneously, eliminating unbalanced line conditions which can cause high-current surges through the protected equipment.

Six of these units have been built and two have been installed. The remaining four units will be installed during the next team moves.

A series of tests were conducted by personnel from the observatory group on another VELA contract to evaluate these protectors for use in protecting field instrumentation at the seismological observatories. The following conditions were simulated:

a. Damage to a galvanometer with damage to the protection diodes;

b. Twisting the mirror on a 3 cps Galvanometer, Model 4100-213. A 40 kV power supply was used to charge two 18.5 microfarad capacitors to various known voltages. The circuit arrangement and modes of coupling used are shown in figure 12.

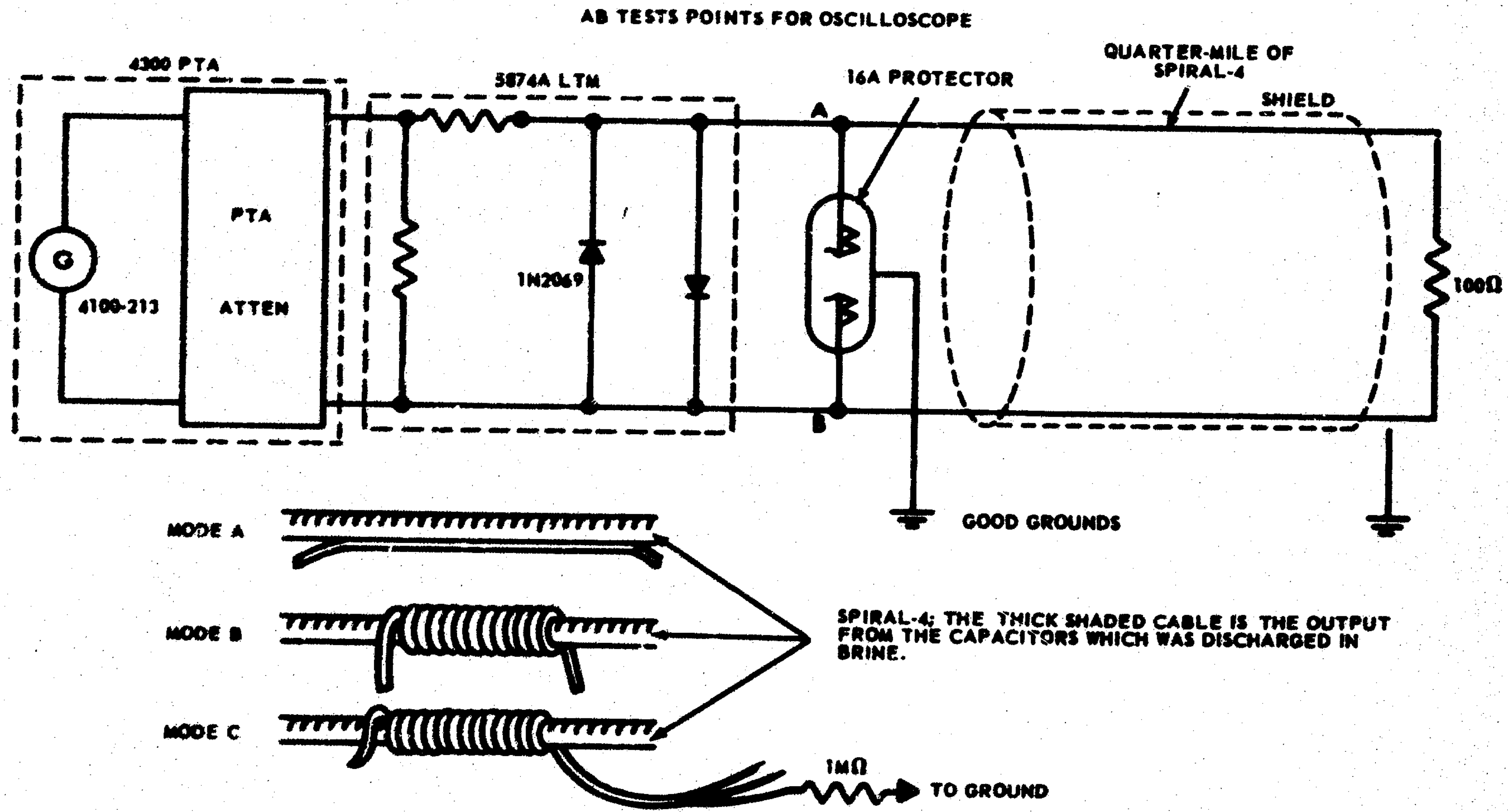


Figure 12. Lightning protection test setup for three modes of coupling

G 1732

The three methods of coupling used to induce the discharge voltage from the capacitors into the signal circuit were:

a. Capacitive coupling: output cable laid parallel to the spiral-four (mode A);

b. Inductive coupling: spiral-four wrapped around the output cable (mode B);

c. Resistive-inductive coupling: same as in mode B, but with one conductor of the spiral-four leaking to ground through a 1-megohm resistor (mode C).

The tests were started with mode A and maximum PTA attenuation. The deflection of the galvanometer mirror was observed during each discharge and photographs of the induced voltage were taken at the AEI protector. No deflection was observed at the galvanometer in either mode A or mode B. The two 18.5 microfarad capacitors were charged to a maximum of 12,000 V and a peak induced voltage of 10 to 15 V was recorded at the protector. The PTA attenuation was eventually reduced to 0 dB and the shield of the spiral-four was grounded without apparent effect.

In mode C, the capacitors were charged to a maximum of 17,000 V and a peak induced voltage of 340 V was observed at the protector. There was no damage to the galvanometer. A drawing of the induced pulse is shown in figure 13.

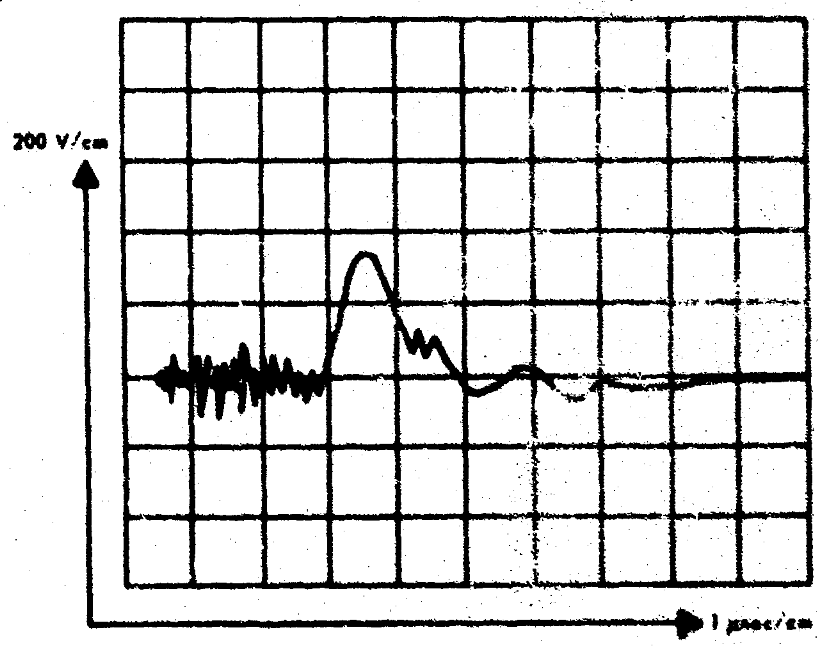


Figure 13. Drawing of the voltage pulse induced at the protector by the discharge of capacitors charged to 17000 V. Resistive-inductive coupling (Mode C)

G 1733

The field ends of the spiral-four conductors remote from the PTA input were shorted and the capacitors were discharged directly down the conductors. With this configuration, it was possible to damage the galvanometer coil.

A setup for twisting and damaging the galvanometer mirror was produced by discharging the charged capacitors into the midpoint of the shield on a 1/4-mile length of spiral-four. The test circuit is shown in figure 14. The spiral-four line was terminated with a seismometer and an AEI protector at the field end of the system. The capacitors were charged to 10,300 V and then discharged. A peak voltage of approximately 1200 V with a rise time of 1 microsecond was induced into the circuit at the protector. This voltage twisted the galvanometer mirror without damaging the protectors. The waveform recorded is shown in figure 15. The tests showed that an adjustable period galvanometer was no more susceptible to flipping than the fixed period galvanometer.

Similar tests were repeated, using a galvanometer suspension restrained by retaining bridges. The capacitors were charged to approximately 15,000 V and discharged without damage to the galvanometer.

Experiments were also conducted to improve galvanometer protection at the PTA. Eighty μH inductors made with 50 turns of #20 wire wound on Arnold A-066032-2 cores were placed at points A and B in the circuit in figure 14. The system was subjected to the discharge of the capacitors charged to 15,000 V without damage to the galvanometer. It was concluded that suitable inductors placed in the data lines will significantly improve the protection afforded the galvanometer during field operations.

It was also found during the experiments that the AEI protector requires an effective ground connection, and when properly grounded, will provide reliable trouble-free protection.

4.6 MAGNETIC-TAPE RECORDERS

4.6.1 Ampex Model 314

The Ampex Tape Recorder, Model 314, continues to serve as the primary recorder in the LRSM mobile seismograph systems. These recorders have been very reliable and there have been no major failures associated with their operation. Numerous minor problems have required attention and preventive maintenance to keep them from becoming serious. The problems associated with the Ampex recorder are discussed in section 5.5 of Geotech Technical Report No. 66-78 and will not be repeated in this report. The only modification performed during this report period was the incorporation of a viscous damped tape supply unit. This modification is discussed in section 7.6.1.

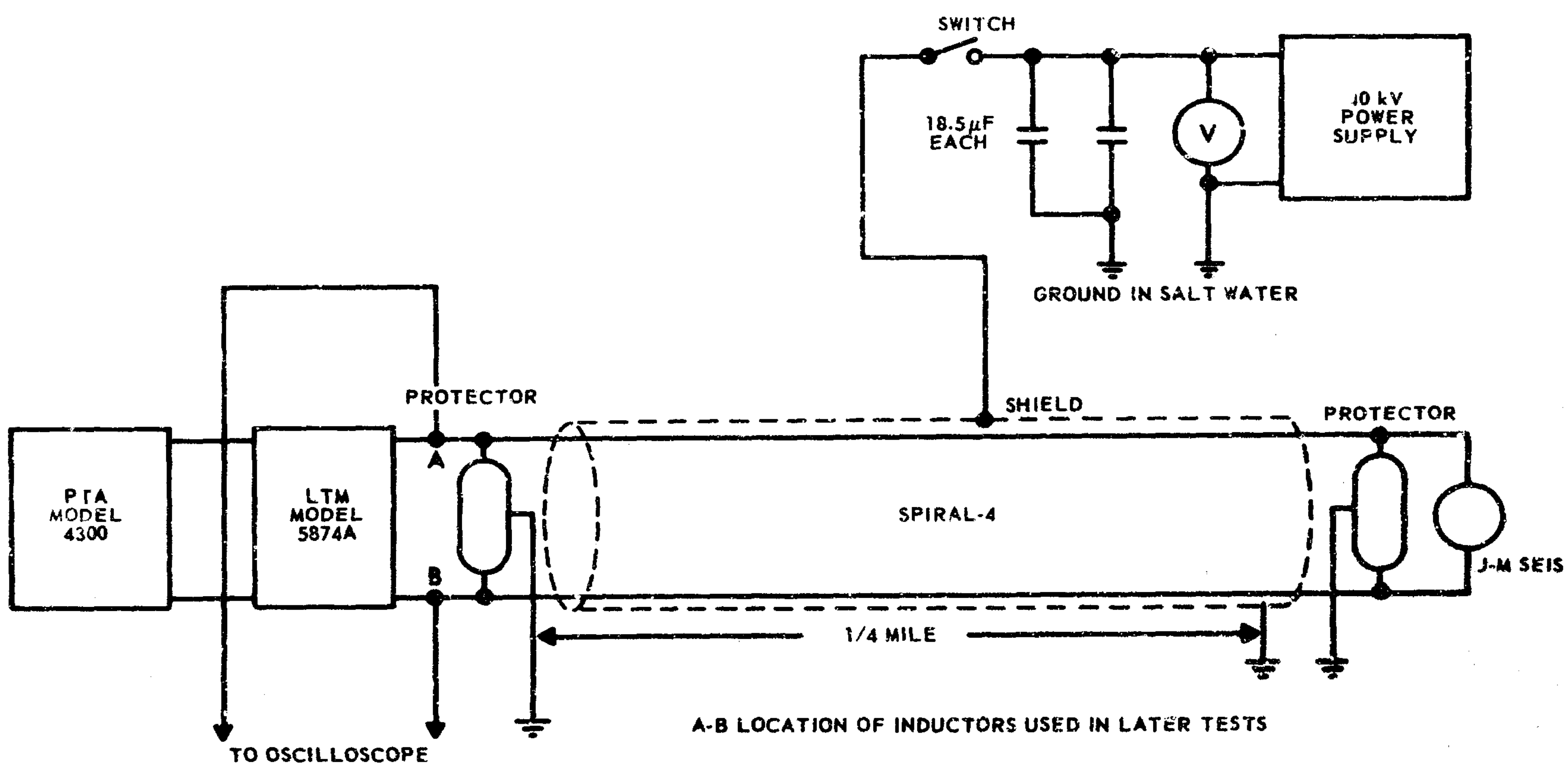


Figure 14. Model of the test system, with a means or damaging the PTA galvanometer and thus simulating lightning effects

G 3734

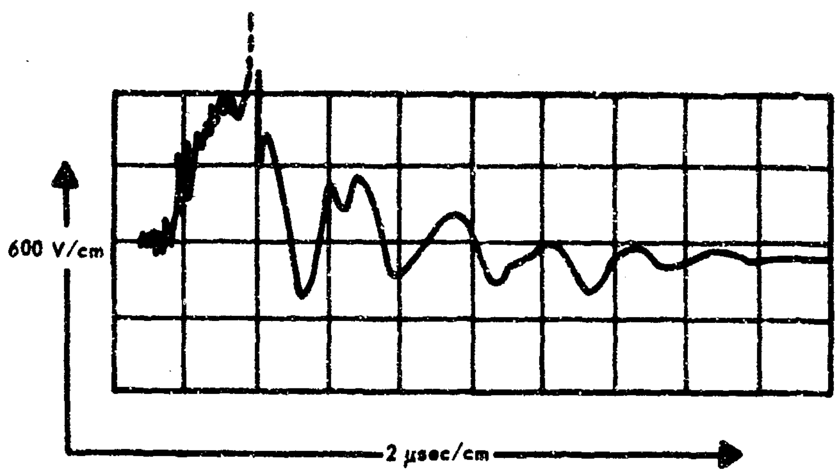


Figure 15. Drawing of the voltage pulse induced at the protector by the discharge of capacitors charged to 10,300 V

4.6.2 IRIG Compatible Slow-Speed Tape Recorder/Reproducer, Model 17554

The Model 17554 magnetic-tape recorder was evaluated by LRSM teams under field conditions. This recorder is a dual-speed (0.03 and 0.06 ips) 14-channel (IRIG) recorder with 2-channel playback capability. It operates from a 24 Vdc center-tapped source. The following discussion is a summary of the field evaluation program:

a. It was found that the regulation of the dc supply voltage to this system is critical. The supply voltage must be maintained as close as possible to a balanced ±12 Vdc. If correct operating voltages are maintained, the VCO frequency drift will be reduced to a minimum. The recorder also has an adjustable ±9 volt regulator that will compensate for a small amount of unbalance in the supply voltage. If the unbalance is too great, the system cannot be properly aligned.

b. The tape transport in this unit is practically trouble free and contributes very little noise to the system.

c. The relays on the VCO printed circuit cards that change the center frequency of the VCO when the speed is changed from 0.03 ips to 0.06 ips were a source of trouble. These latching relays are actuated by a charging capacitor. These relays will not operate properly unless speed changes are separated by at least 5 seconds.

Two filter capacitors mounted above the inverter have leaked several times causing damage to the inverter electronics. No other problems have been encountered at this time.

4.6.3 Magnetic-Tape Recorder, Model 19429

The Model 19429 tape recorder is used in the portable seismograph system. It provides 14 channels of recording capability conforming to IRIG and VELA-Uniform magnetic-tape recorder specifications. This unit was evaluated during the test program for the portable system. The results of this evaluation are published in Technical Report No. 65-7.

Despite problems with an improperly adjusted tape supply clutch, this recorder has operated with high reliability. The adjustment of the supply clutch can be easily performed in the field.

4.7 FILM RECORDERS

4.7.1 Film Recorder, Geotech Model 1301A

The Geotech Film Recorder, Model 1301A, continues to serve as the primary recording system in the LRSM mobile seismograph. The occasional problems with these units are:

a. Poor focus resulting from bad lamps or misaligned optics;

b. Failure of galvanometers;

c. Failure of drum drive mechanism;

d. Leakage of light through the case to the film.

The most prominent problem in the operation of the recorder is an out-of-focus condition on the last 2 or 3 inches of the film. This is caused by the additional thickness of film at the point where it overlaps on the drum. The focus of the optics is so critical that when the light beam records on this section of the film the resulting trace is out of focus.

4.7.2 Develocorders

The Develocorders used in the LRSM program operated satisfactorily, considering the problems imposed by field operation.

The environmental conditions that are encountered in the field generally exceed the operating specifications of the Develocorder. Impurities in the local water supplies have also caused poor processing of the records. Filters

are now being used to eliminate foreign matter in the processing water supplied to the recorder. These filters have helped reduce clogging and residue buildup in the water supply system.

The film drive system in the Develocorders has failed periodically. The cause of these failures was never fully understood, but improved performance was realized by adhering to a strict preventive maintenance schedule.

4.8 HELICORDERS

4.8.1 Model 2484 Helicorder

The Model 2484 Helicorder continues to operate with high reliability except for infrequent failure of the stylus assembly. However, the stylus is expendable and can be easily replaced. No major failures have been experienced in the operation of the Helicorder Amplifiers, Model 4983.

4.8.2 Model 12400 Helicorder

The Model 12400 Helicorder is used as an auxiliary unit for monitoring and calibrating the portable seismograph system. It is battery powered and can be used in isolated locations.

As with the Model 2484, the most frequent problem in the operation of this recorder has been stylus failures. Other problems generally have been associated with the electronics. Cold solder joints, transistor failures, diode failures, and resistor failures have occurred. One of the major complaints by operators of this unit is the difficulty encountered in the repair and troubleshooting of the electronics, which are of the circuit board type of construction. The prime design requirement of the instrument was portability, and the unit was packaged with the foremost object of saving space and weight. The electronics are packaged so that when a failure occurs, it is necessary to partially disassemble a large portion of the recorder in order to replace components.

4.9 TIMING SYSTEMS

4.9.1 Model 5400-M2 Timing System

The 5400-M2 timing system is the primary timing system of the mobile observatories. The operating characteristics of this instrument were originally rather unreliable and unstable. A program was initiated to modify the components, as required, to overcome the system's shortcomings. This program was completed in 1963 and the system has since operated with far fewer failures and with improved accuracy. The improvement program included the installation of Inverters, Model 9220, in all systems operating

the modified timing system to provide a more reliable source of frequency regulated secondary power. The inverter has a continuous dc input; however, the output is used only when the primary power from the timing system fails. Failure of the primary power automatically switches the system to secondary frequency regulated power.

During the past 21 months, the following number of components have failed:

Unit	Number of failures
Programmer	53
Stroboscope	32
Frequency standard	18
Control unit	8
Power unit	20
Frequency divider	16
Interconnecting wiring	2

Most of these failures are attributed to the age of the units - now 5 to 7 years. In an effort to further improve the reliability of the station timing, the newly developed Timing Systems, Model 19000, were purchased to replace the Model 5400-M2 systems. Sixteen new systems have been placed on order and are scheduled for delivery during September 1966.

4.9.2 Timing System, Model 19000-M1

The Timing System, Model 19000-M1, is the primary timing system used in the portable seismograph system. It features plug-in printed circuit board construction for ease in troubleshooting. The unit has provided reliable and stable operation with drift rates of less than 5 milliseconds a day in many instances. There have been very few problems encountered in the operation of this instrument.

4.9.3 Radio Receivers

a. Hammarlund, Model SP600. The Hammarlund SP600 is a general purpose communications receiver used to monitor WWV time broadcasts in the mobile observatories. It continues to operate satisfactorily, requiring only routine maintenance.

b. Specific Products, Model WVTR. The Radio Receiver, Model WVTR, was used in the original engineering model of the portable seismograph system. This receiver adequately met the requirements of the specifications for the portable system. However, this receiver was abandoned in favor of a Gertsch, Model 1910, receiver when the five additional portable systems were built, because the Gertsch receiver was more sensitive and had a wider operational temperature range than the Specific Products receiver

for approximately the same cost. The Specific Products receiver has operated satisfactorily in the original portable system during 24 months of field operation. It is well suited to portable applications.

c. Gertsch, Model 1910. The Gertsch Receiver, Model 1910, figure 16, was installed in the production version of the portable seismograph system. Five of these units have been in operation since September 1965. No failures have been experienced during this period, and they have operated satisfactorily.

4.10 CALIBRATION

Calibration of the LRSM seismograph encompasses the following:

- Electromagnetic calibration
- Weight-lift calibration
- Long-period polarity checks
- System phase response

The paragraphs below present an evaluation of each of these calibration techniques.

4.10.1 Electromagnetic Calibration

The electromagnetic type of calibration is applied to both the LP and SP seismographs. These calibration systems have operated very reliably during this reporting period. No modifications have been performed on any of the components.

4.10.2 Long-Period Polarity Checks

A polarity checking system is incorporated on the long-period seismographs to provide a method for confirming that the detectors are properly connected and oriented. The major problem associated with the operation of these units has been crosstalk or leakage of the applied voltage into the seismograph signal circuit. The routing of the polarity checker power line through the base terminals of the seismometer was determined to be the source of this leakage. This condition was generally improved by routing the power line through the mass position unit input connector.

4.10.3 System Phase Response

The phase response of a seismograph system can be calculated from the signal resulting when a dc pulse is applied to the electromagnetic calibration coil. The Fiducial Control Unit, Model 17086, was designed to produce a timing pulse on the recorders that is coincident with the onset of the calibration pulse. The unit has operated satisfactorily after being modified to reduce crosstalk to an acceptable value (see section 7.10.2).

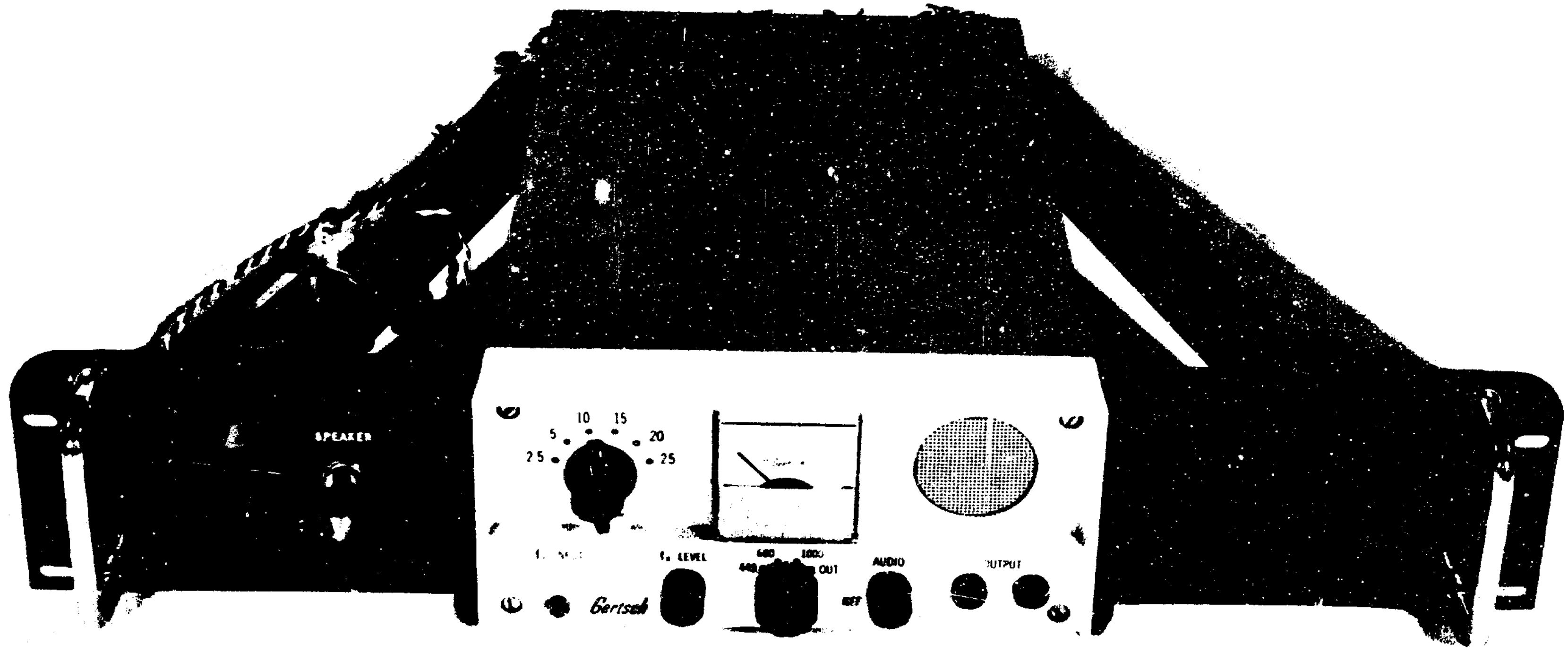


Figure 16. Gertsch Radio Receiver, Model 1910

G 1735

4.10.4 Weight-Lift Calibrations

Weight-lift calibrators of the types shown below are used in all short-period seismographs.

Seismometer	Calibrator
Portable Short-Period Horizontal, Model 6102A	Ball-Lift Calibrator, Model 10059
Portable Short-Period Vertical, Model 4681	Ball-Lift Calibrator, Model 8330
Short-Period Horizontal Benioff, Model 1101	Ball-Lift Calibrator, Model 5528
Short-Period Vertical Benioff, Model 1051	Ball-Lift Calibrator, Model 5227
Portable Short-Period Seismometer, Model 18300	Weight-Lift Calibrator, Model 23373

All of the calibrators used on the Benioff seismometers are of the same general construction in that the calibrator weight is exposed to the environment. The major problems associated with the operation of these units include sticking weights resulting from moisture or residual magnetism, and inductive crosstalk to the signal lines. These problems are not severe enough to significantly affect the calibration accuracy.

The Model 23373 calibrator used on the Model 18300 seismometer is designed with the weight sealed. Moisture therefore does not affect its operation. The effective weight of the unit can be varied by an adjustment screw. This calibrator, installed on a seismometer, is shown in figure 17. This type of calibrator is superior in performance to the other types of weight-lift calibrators.

4.11 POWER SYSTEMS

4.11.1 Nicad Batteries

The nickel-cadmium battery banks used in the LRSM system have been a reliable source of dc power. Only preventative maintenance has been required for these units. This maintenance has consisted of coating the terminal posts with lubricant to prevent corrosion, maintaining the proper level and specific gravity of the electrolyte, maintaining a layer of cell oil on top of electrolyte to prevent evaporation, and monitoring cell voltage.

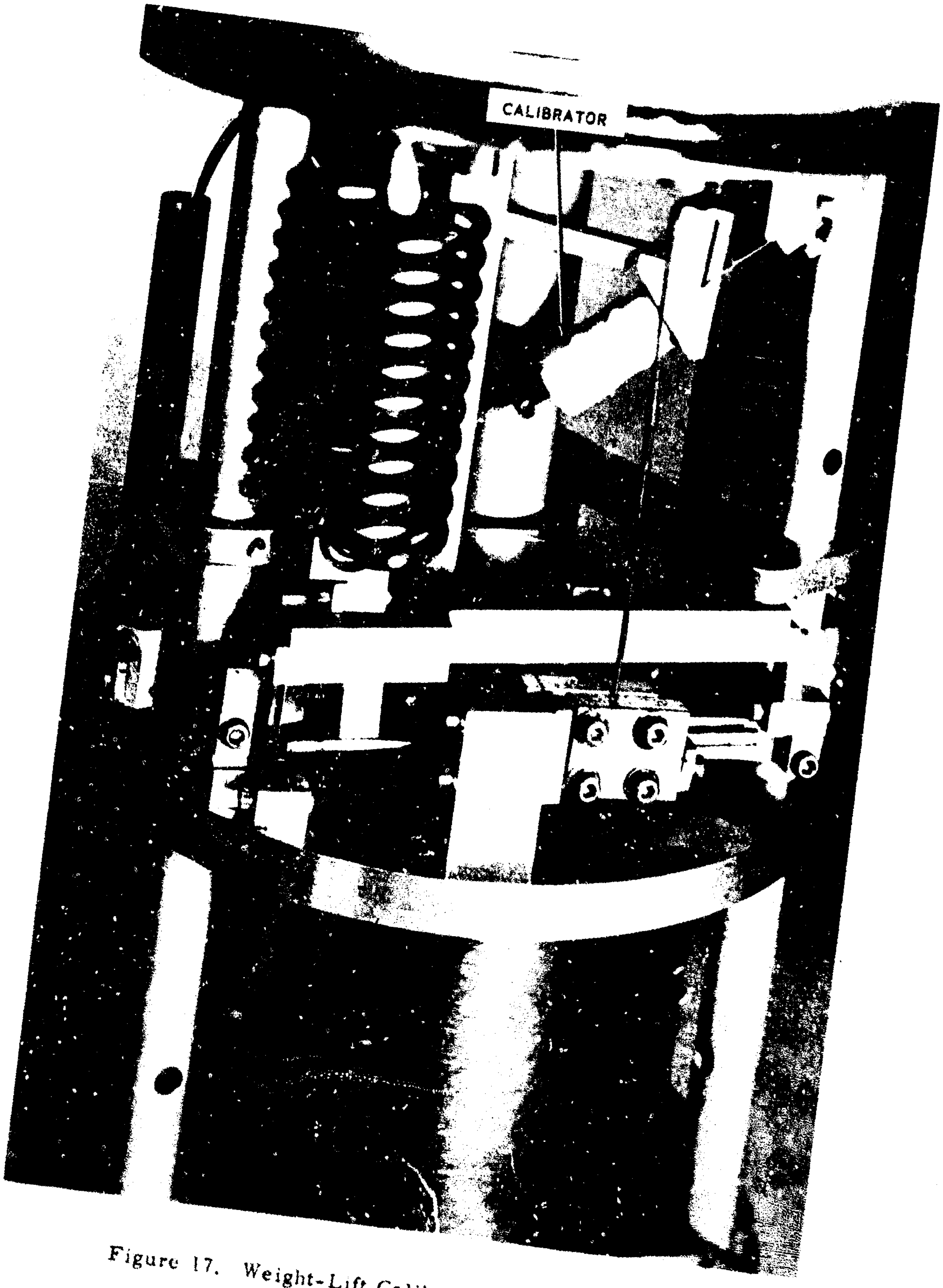


Figure 17. Weight-Lift Calibrator, Model 23373

G 1736

4.11.2 General Radio Regulator

The General Radio voltage regulator is used as the power source for the magnetic-tape recorder. It has been a reliable source of regulated power, requiring only routine maintenance.

4.11.3 Inverter, Model 10050A

The Model 10050A inverter is used to supply 115 volts, 240 cycle, frequency-regulated power to the PTA's. It has been a satisfactory source of power and has required minimum maintenance.

4.11.4 Batteries and Thermoelectric Generators for Portable Systems

The portable systems use a bank of silver-zinc batteries and thermoelectric generators as alternate power sources. Several battery failures have occurred. The cause of these failures appears to be either malfunctioning of the battery charger circuitry or overcharging of some of the cells. The cells do not become charged at equal rates, which allows some of the cells to become overcharged before the charger shutoff voltage is reached. One cell has been returned to the manufacturer, Yardney Electric Company, for evaluation; however, no conclusion as to the exact cause of failure has been reached.

The thermoelectric generators have functioned with a minimum of maintenance. The output of several of the units dropped below the rated value. Examination by the manufacturer, 3M Company, indicated the cause to be an error in manufacturing, and the defective units are being replaced.

5. EVALUATION OF SUPPORT EQUIPMENT

5.1 GENERAL

Support equipment is defined to include instrumentation shelters, vehicles, and generators. The support equipment discussed in Interim Report No. 2, LRSM Program, remains in use at the field sites with the exception of new seismometer vaults and some replacement vehicles. No modifications to the support equipment were implemented during this report period.

5.2 INSTRUMENT SHELTERS

5.2.1 Instrumentation Vans

The Model 8513 and 7700 vans are unchanged.

Twenty-three vans were transferred to other governmental agencies or projects during this period. Table 2 contains a chronological history of each van transfer, the serial number of each van, and the receiving agency. Sixteen vans are presently being operated in the LRSM program.

Table 2. LRSM mobile observatory transfers

Date of transfer	Team	Receiving agency or project	Serial No. of van
30 Nov 1964	29	T/5003	201
15 Dec 1964	6	USGS	225
15 Dec 1964	2	USGS	215
30 Dec 1964	12	USGS	220
6 Jan 1965	22	USGS	227
2 Feb 1965	9	USC&GS	207
15 Feb 1965	19	AFOSR (Bolivia)	230
1 Mar 1965	34	AFOSR (Germany)	217
1 Apr 1965	20	AFOSR (Norway)	216
9 Apr 1965	4	AFTAC	203
9 Apr 1965	5	AFTAC	2[illegible]3
9 Apr 1965	10	AFTAC	224
15 Apr 1965	14	AFTAC	209
30 Nov 1965	24	AFTAC	202
1 Dec 1965	26	AFTAC	204
3 Jan 1965	7	T/6058	237
3 Jan 1965	17	T/6058	234
3 Jan 1965	25	T/6058	221
3 Jan 1965	1	T/6058	212
3 Jan 1965	31	VT/5051	231
17 Jan 1966	23	U. S. Corp of Engineers	228
31 Jan 1966	39	AFCRL	238
22 Mar 1966	40	ESSA	218

5.2.2 Phototube Amplifier Shelters

The new phototube amplifier shelters discussed in Interim Report No. 2 are being used at each of the field sites. The design changes in the new shelter did not alter the shape or size of the original units and thus there is no change in the basic concrete foundation slab.

5.2.3 Portable System Shelters

The design and construction of the portable system Shelter, Model 19854, has proven to be satisfactory. This shelter, with the portable system components installed in it, is shown in figure 18. A radiant type propane heater was mounted in the shelter to maintain temperature above the low temperature specification.

5.2.4 Seismometer Vaults

The construction techniques used for short-period and long-period seismometer vault installations are basically unchanged since 1962. However, the half-shell metal tanks have been replaced with a solid wall tank vault as shown in figure 19. These vaults are of heavy, flanged construction, consisting of a lid and a one-piece cylinder. Their size and shape are essentially the same as the half-shell vaults. The concrete base pier for the vaults and the surrounding wooden earth-retainer box are unchanged. These vaults are easier to seal and are more durable. The polysulfide sealing compounds used on the concrete floor of the vaults and vault concrete joints have yielded excellent results.

The earth-retainer boxes are not coupled to the concrete pier and the space between the vault and the retainer boxes has become flooded at some locations. In addition, vault excavations form excellent water traps in areas of poor drainage. The construction of vault drainage facilities appears to be the best method of preventing flooding. In areas where natural drainage is particularly insufficient, extensive drainage systems have been required.

Due to the temporary nature of portable system operations, a temporary vault installation technique has been developed. The installation technique is illustrated in figures 20 and 21. This type of installation has proven to be satisfactory for operational periods of 2 weeks to 1 month. If site operations are anticipated in excess of 1 month, metal tank vaults should be installed.

5.2.5 Severe Weather Clothing

Each portable system operator was supplied with arctic foul-weather clothing (figure 22). This clothing was issued when the systems were scheduled to become operational in arctic climates. When not in use, the clothing is stored in the Geotech warehouse. The standard issue of arctic clothing is a parka, overpants, insulated boots, and storage bag.

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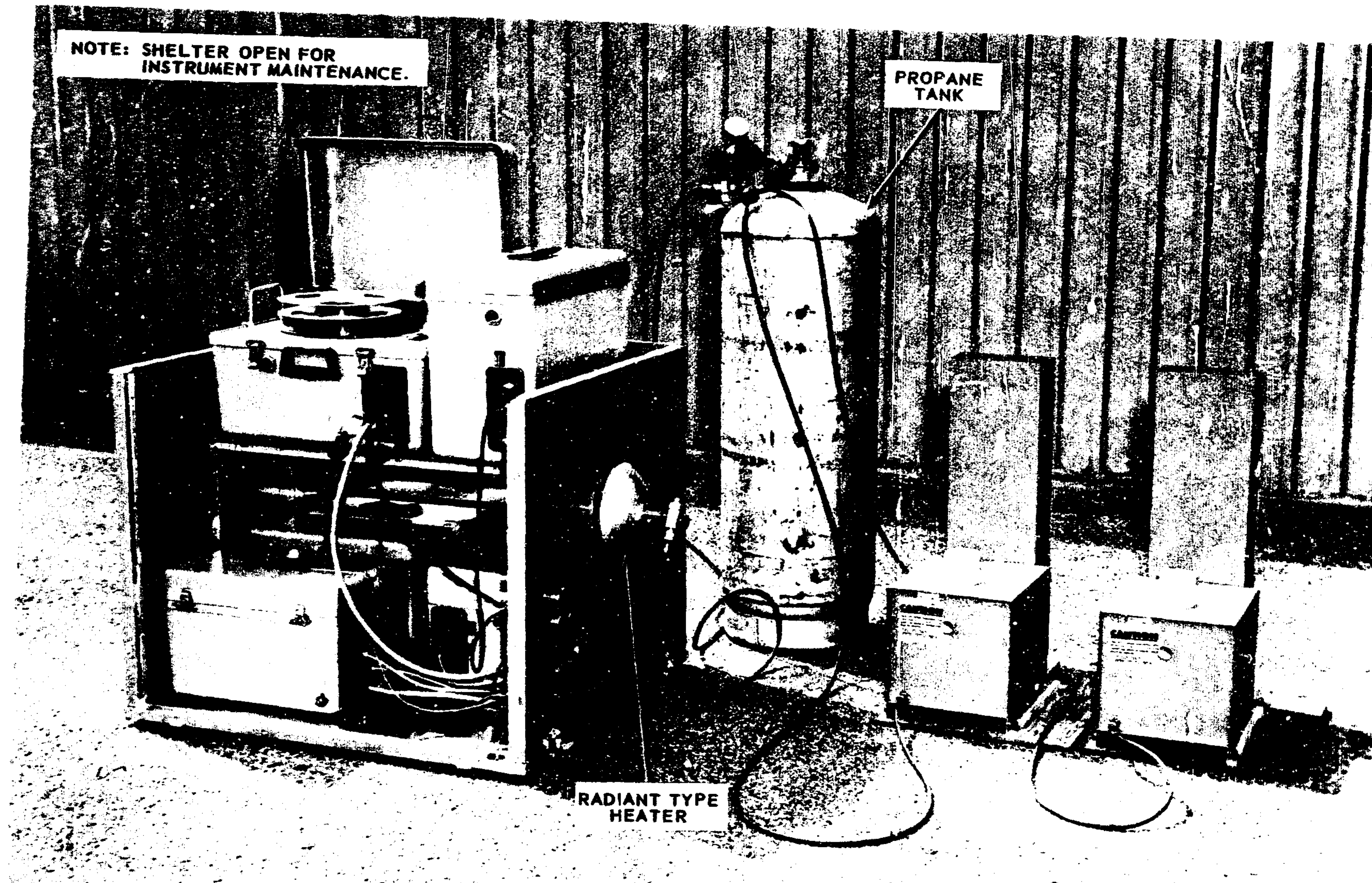

Figure 18. Portable system shelter and radiant heater

G 1737

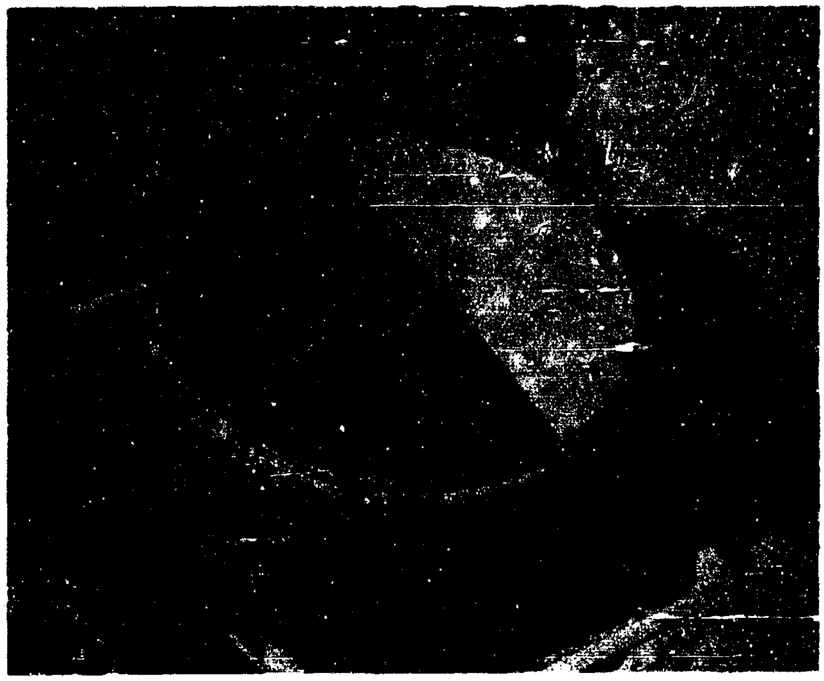

Figure 19. One-piece Tank Assembly, Model 23232A
G 1738

5.3 VEHICLES

The vehicles discussed in this section are:

a. Heavy-duty personnel carriers and pickup trucks used for personnel transportation and for transporting light loads to and from the site;

b. Heavy-duty pickup trucks used for moving the instrumentation vans during station moves and for transporting equipment on site;

c. Special purpose vehicles used when the vehicles normally assigned to a team are inadequate for the assigned task;

d. Utility trailers used for transporting generators and equipment in the field.

Since the start of the LRSM program, approximately 5 million miles have been driven using contract vehicles. Although 1.5 million miles were driven during this report period, only 11 accidents were reported. A total of 117 accidents involving LRSM vehicles have been reported since the beginning of the program, but in only one instance was a team member hospitalized due to injuries received in an accident.

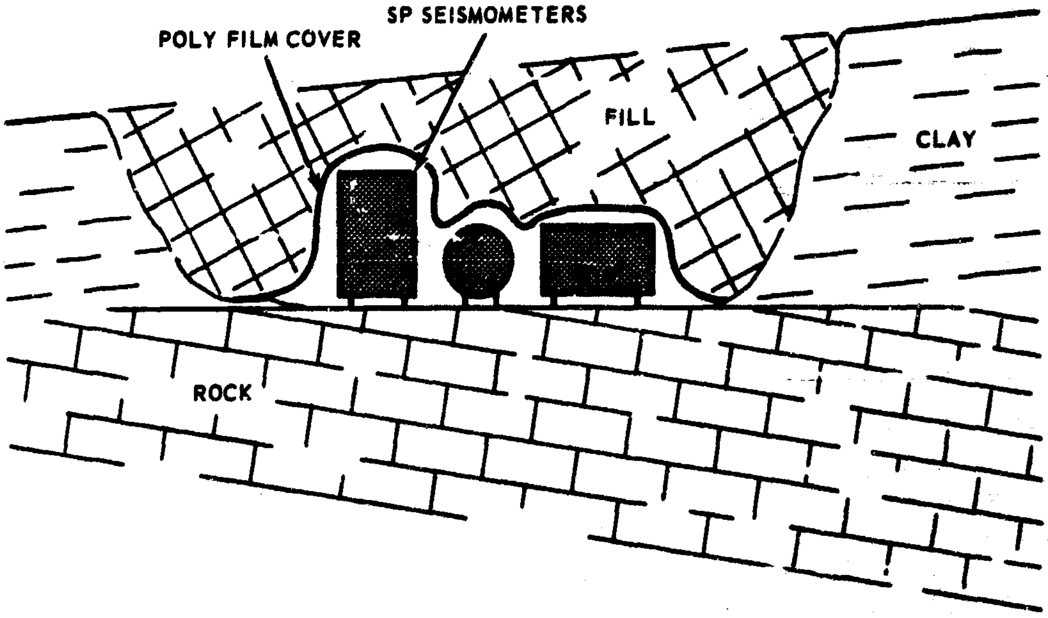

Figure 20. Typical short-period seismometer installation

G 1395

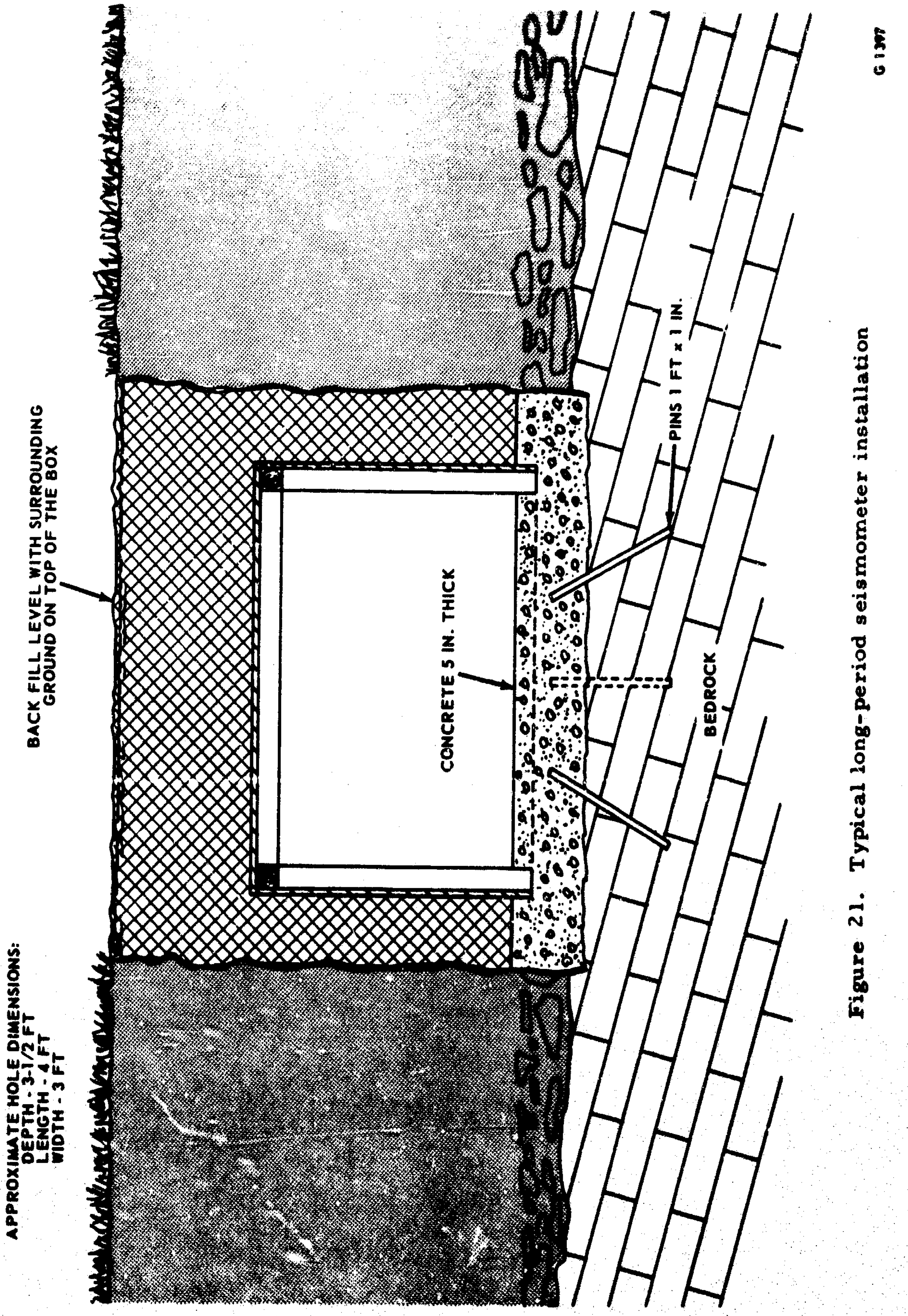

Figure 21. Typical long-period seismometer installation

Figure 22. Arctic clothing provided to portable system operators G 1393

5.3.1 Heavy-Duty Personnel Carrier

At the close of this report period, 12 of the original 40 personnel carriers remained in use in the LRSM program. Each of these vehicles has been driven an average of 71,000 miles. These units have been in constant service during the past 5 years, providing adequate transportation for the field teams. However, the operational and maintenance costs of these vehicles are becoming excessive as their mileage increases. At present, only four of these units are in daily operation. The remaining vehicles are kept in readiness at the Garland plant to be used in portable system operations or for field support functions.

5.3.2 Heavy-Duty 3/4-Ton Pickup Trucks

At the end of March 1966, 17 of the original 40 pickups remained active in the LRSM program. The average mileage for each of these units was 52,700. The greatest part of this mileage has been accumulated on unimproved roads in inclement weather. This type of driving subjects these vehicles to a great deal of abuse from vibration and damage from gravel thrown by passing vehicles. The remaining mileage has generally been accumulated towing the instrumentation vans during team moves. The average operational cost for these vehicles during this report period has been 17 cents per mile.

In December 1964, a shutoff valve was installed in the vacuum brake lines on these pickups. This modification was designed to eliminate the possibility of vacuum leaks, causing excessive burning of the valves in these engines. This valve is opened only when the pickup is used to haul the instrument van. However, the vacuum booster continues to operate for the truck brakes when the valve is closed.

5.3.3 Heavy-Duty 1/2-Ton Pickup Trucks

Ten heavy-duty, 1/2-ton pickup trucks were acquired in August 1965 on a leasing agreement. These units were obtained to replace those personnel carriers that, because of their high mileage, had become unreliable and uneconomical to maintain. On 31 March 1966, the average number of miles per pickup truck was 15,200 - a large part of this mileage being accumulated on unpaved roads. These units have provided personnel transportation at low operating costs. The specifications for this vehicle are presented in appendix 1. In addition to the listed specifications, a vacuum brake system was installed which uses a hand-operated actuator mounted on the steering column of the truck. This modification permitted use of the utility trailers' vacuum-actuated brakes. Included in this modification was the installation of a vacuum brake line shutoff valve near the engine manifold to prevent leaks that might develop in the vacuum brake system from disturbing ignition timing and decreasing engine efficiency.

5.3.4 2-1/2 Ton Truck

The numerous failures of the 3/4-ton heavy-duty pickups while towing instrumentation vans during 1962-1963 indicated that a more suitable vehicle was needed to furnish a reliable means of transporting the vans over long distances. In October 1964, a 2-1/2 ton truck was leased to fulfill this requirement. This unit is dispatched from Garland when a van move is to be undertaken and is not used for personnel transportation. This vehicle has been driven over 47,000 miles with few mechanical breakdowns. The only serious failure occurred while the unit was still under warranty. An oil pump failure necessitated an engine replacement. The operational cost for this unit is approximately 20 cents per mile, but the greater degree of personnel safety and the decrease in travel time during team moves justify this cost. The use of this vehicle was so successful that a second unit was leased in March 1966. The specifications for these vehicles are presented in appendix 2. Figure 23 shows a rear view of the initial unit.

5.3.5 Cable Trucks

The two well-logging trucks, a 1957 Dodge, Model 500, and a 1960 Chevrolet, Model 800, were used successfully at sites which operated deep-hole instrumentation. No significant problems were encountered in their operation. These vehicles were transferred to Project VT/5051 when they were no longer required by the LRSM program.

5.3.6 Kristi Snow Vehicle, Model KT-3

In October 1962, a Kristi, Model KT-3, snow vehicle was purchased for use at the PM-WY site. This tracked vehicle provides safe, dependable transportation in areas with heavy snow cover when roads are impassable to wheeled vehicles. This vehicle was used successfully during the 1964-1965 winter season in support of the LASA operations in Montana and during the winter of 1965-1966 at both the RK-ON and SV3QB locations. The operational costs of this vehicle have been slight. The greatest expense for this unit has been the transportation costs incurred in transferring it to a new location. The specifications for this vehicle are listed in appendix 3.

5.3.7 Utility Trailers

The 13 utility trailers currently in use in the LRSM program are used to transport generators and instrumentation in the field. These units have been used extensively during portable system operations and team moves. Two trailers were surveyed during this period due to extensive damage and uneconomical restoration costs. The surveyed trailers have not been replaced, due to the reduction in program effort. The operational costs for the utility trailers have been low, with the major expenses being incurred for licensing and tires.

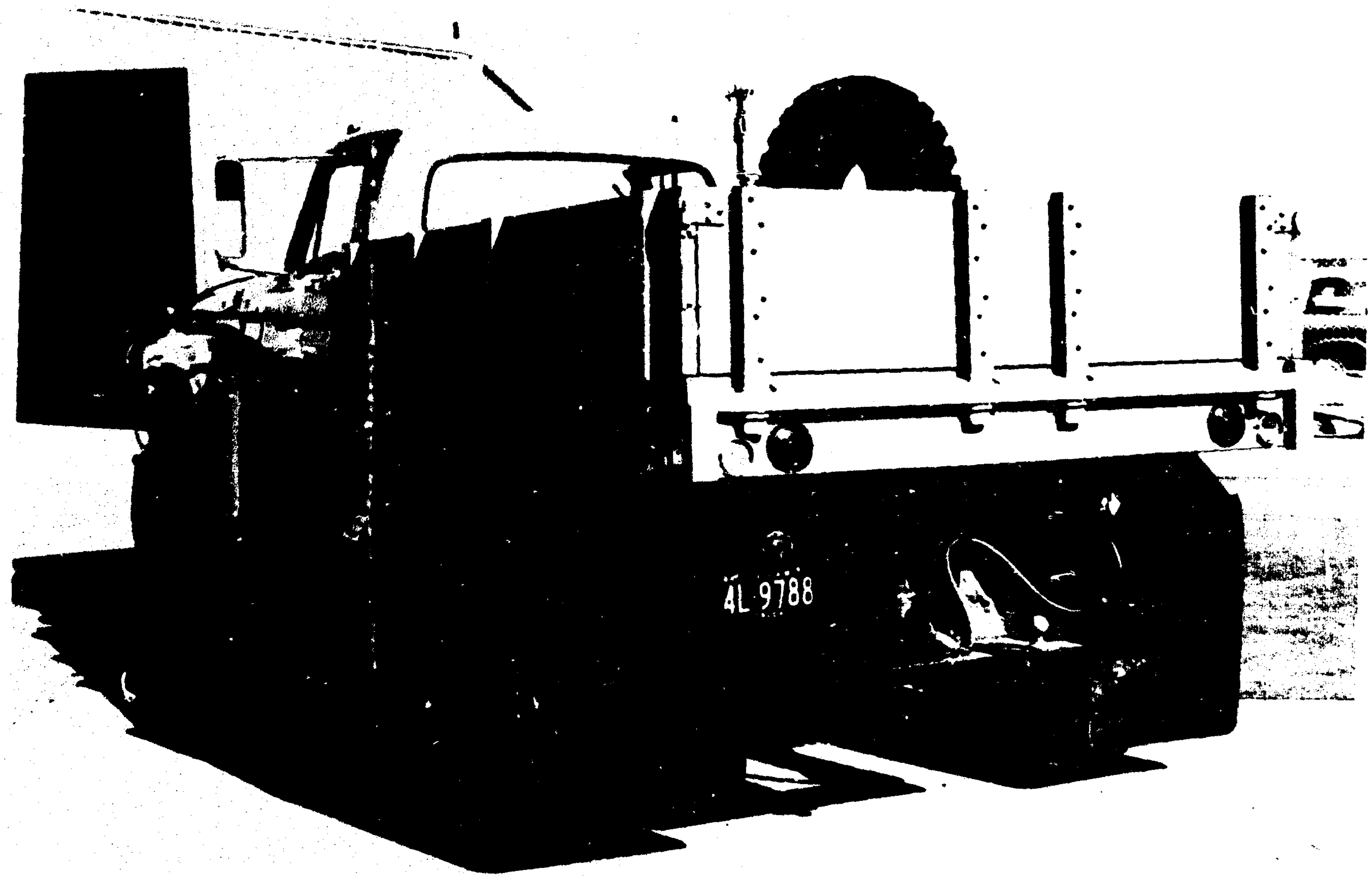

Figure 23. 2-1/2 ton truck, rear view

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5.4 GENERATORS

At the close of this report period, 19 U. S. Motors and 1 PE-95, 15-KVA generators were available for use at locations where commercial power could not be economically obtained. The PE-95 was originally furnished as GFE with instructions to survey the unit when major repair was necessary. This generator is presently being utilized as a backup generator. Six of the U. S. Motors' generators are in service at field locations and the remaining 13 units are located at the Garland plant. The generators have performed satisfactorily under many different climatic conditions. However, as the number of operating hours increase, repairs are becoming more frequent and operational costs are increasing correspondingly. Several of the units located in Garland are maintained in an operational status and can be sent to the field on short notice.

In addition to the twenty 15-KVA generators, five Caterpillar 30-KVA diesel generators were in use during this report period. At present, two of the units are being operated at sites as the primary power source, and a third unit is used as a standby generator at the NP-NT site. These generators have provided reliable service for extended periods of time. The remaining two generators have been transferred to other agencies.

Four Onan 25-KVA diesel generators were purchased during this period. Three of the four were soon returned to the factory for engine repair or replacement. However, since their service had been unsatisfactory, a factory adjustment was made and these units were not returned to service. The remaining Onan generator was transferred to another agency.

Four teams are operating on generator power; each team has two generators available for use. A PE-95 generator is located at the Kanab, Utah, site as a third generator. In addition, one team is operating on commercial power with a generator available for emergency use.

6. EVALUATION OF SEISMOGRAMS

6.1 GENERAL

Two groups within the Data Reduction Section have the responsibility for the evaluation of the quality of all seismic data produced by the field teams. The primary responsibility of the Data Control group is to examine 35 mm records, 16 mm records, and the associated operations logs. The Special Presentations group has the responsibility for the critique of magnetic-tape recordings and magnetic-tape operations logs. The fundamental purpose of these critiques is to maintain the professional quality of the seismograms produced by the field teams. Critique Check Lists and the LRSM Field Operations Manual, which

establish the operational tolerances, are the guides used by each group during a critique. Each field team has received an average of four fritiques a month during this report period.

6.2 FILM QUALITY CONTROL

Film records and operational logs are carefully checked according to the Critique Check List and the operational tolerances. Critiques are issued on the basis of two crituques per team per month. Critiques are also performed upon special request from the field team supervisors.

The film records are viewed at X20 magnification. Time corrections are taken, calibrations measured, and malfunctions noted. System magnifications are computed and compared with those reported by the team. The analyst then writes an objective critique and computes a grade score. An example of a 35 mm film critique is shown in figure 24. A computer program has been written to determine grade averages and mean deviations. Table 3 is a play-out of this program for the 21 months covered by this report.

6.3 MAGNETIC-TAPE QUALITY CONTROL

Magnetic-tape records from each site are selected for review on a random basis. Each tape record is evaluated primarily for signal and calibration levels, system alignment, and timing accuracy; operations logs are checked for completeness, accuracy, and neatness.

During January 1966, the Special Presentations group introduced a new quality control grading system. Grading under this system is on a point credit basis; that is, points are given for each correct performance. When any deficiency occurs, points will not be credited. Figure 25 is a copy of the tape recording Critique Check List. There are 250 points total on the list. After a critique is complete, grades will be determined by dividing the points earned by 250. For example, a point total of 200 represents 80 percent of 250; accordingly, the grade given will be 80. Table 3 shows the average grade received by each team during this report period.

The point distribution throughout the various categories on the check list was changed to more accurately indicate those areas which require the greatest effort to assure the recording of high-quality data.

During the previous 18 months, 1,100 magnetic-tape recordings have been reviewed and evaluated by quality control technicians. Listed below are the difficulties most frequently encountered by field teams as detected and analysed by the Special Presentations group.

Field site - _____
Team No. _____

Supervisor - ________

Critiqued by ________
Date of Critique - 19 April 1965

Date of Film - 13 April 1965
Run No. 103-66

Grade 87
****

1. Record shipment
   1.1 Promptness
   1.2 Packaging

2. Logs and film wrapper
   2.1 Neatness
   2.2 Completeness
   2.3 Accurate measurements
   2.4 Accurate computations

3. Film quality
   3.1 Photography -10
   3.2 Handling -02

4. Data quality
   4.1 Operational Schedule
   4.2 Operational Tolerances
   4.3 Station time
   4.4 WWV reception
   4.5 Irregularities -01

5.2 Excessive points

3. OC Remarks

3.1.A.1. The following film is out of focus less than 3 or 5 minutes on the trailing end of the filmstrip - SPT. (-01)

3.1.A.4. The following film is out of focus intermittently throughout - LPZ-LO. (-07)

3.1.B.1. The optics are out of alignment on the following film - LPZ, LPR, LPT. (-03)

3.1.D.1. The light intensity was high on the following film - Radio, SPZ. (-02)

3.1.E.6. There are chemical stains on the edges of the following filmstrips - SPZ, SPT. (-02)

3.2.A.3. The following filmstrip was improperly trimmed - LPT. (-02)

4.5.F.1. There are trace offsets on the following film - LPT. (-01)

Figure 24. 35 mm Field team record critique

Table 3. Critique grade averages, July 1964 through March 1966

Magnetic tape		Film	
Team	Average	Team	Average
1	90.846	1	85.619
2	88.000	2	91.333
3	85.100	3	79.188
4	92.000	4	85.500
5	86.375	5	86.778
6	85.750	6	80.000
7	84.214	7	81.125
8	87.941	8	80.440
9	70.667	9	85.000
10	86.000	10	82.100
11	94.400	11	85.688
12	91.000	12	91.500
13	85.625	13	83.214
14	86.125	14	87.556
15	87.611	15	74.296
16	89.294	16	78.207
17	90.067	17	86.880
18	92.950	18	87.219
19	89.000	19	77.000
20	89.375	20	86.500
21	86.778	21	78.133
22	82.667	22	89.333
23	86.667	23	83.762
24	88.417	24	85.211
25	90.769	25	84.364
26	88.875	26	84.323
27	85.263	27	78.194
28	85.842	28	77.533
29	86.250	29	92.750
30	88.813	30	82.520
31	91.824	31	94.407
33	90.167	33	82.267
34	77.200	34	65.667
35	86.650	35	81.839
36	83.722	36	78.677
37	87.150	37	78.767
38	86.579	38	80.848
39	89.000	39	84.056
40	89.789	40	84.867
50	90.000		
51	80.000		
52	80.000		
53	87.000		
54	82.500		
55	79.000		
Overall Average	**86.484**	**Overall Average**	**82.889**

Magnetic-Tape Critique Check List

Field Site__________ Team Number__________

Run Number__________ Team Supervisor__________

	CREDIT POINTS		FIELD MANUAL REFERENCE
1. RECORD SHIPMENT			
1.1 Promptness	5	Prompt shipment of tape and tape system logs	Sec I:6.2
1.2 Label	5	Properly filled out data label	Sec I:5.4.2
1.3 Stamp	5	Neat, correctly placed I.D. stamp on tape box	Sec I:5.4.3

2. LOGS

2.1 Completeness

Magnetic-tape log remarks are of extreme importance for advising data processing personnel of all conditions that existed during a recording period. Tape Q.C. will require that remarks be entered to explain any conditions affecting the data recorded. For example, when weather conditions are a factor affecting recorded data these conditions, and the times of any changes, must be described. Consideration will be given where it is reasonable to assume that team personnel could not be aware of unusual conditions. Credit for completeness will be given under the appropriate category being critiqued (Sec I: 4.6.1).

2.2 Neatness	5	General tape system log neatness	Sec I: 4.1
2.3 Accuracy			
2.3.1 Measurements	10	Accuracy of measurements entered on tape system log. ±2%	
2.3.2 Computations	10	Accuracy or computations entered on tape system log. ±2%	

Figure 25. Magnetic-tape critique check list

	CREDIT POINTS		FIELD MANUAL REFERENCE
3. TAPE SYSTEM			
3.1 Tape Speed	5	Maintaining tape transport speed within tolerance (±0.5%) after receipt of notice from Q.C. of an existing tape speed error	
3.2 Tape System Noise (50 cps filter)	20	Maintaining a tape system noise level of 60 mV or less	
	10	Bonus points for noise level consistently meeting specs from critique to critique	
4. MAGNETIC TAPE RECORD			
4.1 Markings	10	Properly marking each tape with team stamp, start time, and first 5-minute mark	Sec. I: 5.4.1
4.2 Leader	5	Taking up 15 turns of tape on takeup reel before starting each day's run	Sec. II: 5.3.4
4.3 Voice Comments	20	Clear, understandable voice comments. Throughout each run	Sec. II: 5.3.5
4.4 Calibration Times	10	Performing calibrations at specified times	Sec. I:2.1.1
4.5 Polarities	5	Maintaining proper polarities	Sec. II: 3
4.6 Channel Priority	10	Following specified channel priority	Sec. II: 5.2
4.7 Tape Alignment	20	Accurately performing the tape system alignment	Sec. II: 5.3.1

Figure 25. Magnetic-tape critique check list (Continued)

	CREDIT POINTS		FIELD MANUAL REFERENCE
4.8 Record Change	10	Proper time of record change	Sec. II: 5.3.4
4.9 WWV	10	Maintaining correct WWV record level during periods of good radio reception	Sec. II: 5.4.3
4.10 Station Time	15	Maintaining correct record level and high-to-low level ratio of 60 cps timing signal on channel #14	Sec. II: 5.3.1
5. DATA			
5.1	20	Maintaining dc offsets within tolerance. Tape system ±40 mV; PTA ±30 mV	Sec. II: 4.5.2
5.2	15	Maintaining proper signal background levels. SP - 60 mV LP - 100 mV ±50 mV	Sec. II: 5.4.2
5.3	25	Maintaining calibrations at specified levels. SP - 2.0 to 2.5 V p-p LP - 0.5 to 2.5 V p-p (measured at 1.0 cps for SP and 0.04 cps for LP)	Sec. I: 2.3.2

Figure 25. Magnetic-tape critique check list (Continued)

a. Station time - During the past 21 months, an average of 16 percent of all operational teams have encountered some form of difficulty with recording station timing. Most problems have been determined to result from oxide buildup on the record heads, resulting in partial or total loss of data. To date, only 0.3 percent of all field data have had unusable timing data.

b. Seismic background levels - An average of 27 percent of all operational teams have recorded seismic background levels in the short-period frequency spectrum either below or above specified levels and 20 percent of the teams have recorded long-period background levels either above or below tolerance limits. Weather and other atmospheric conditions have accounted for 75 percent of these difficulties.

c. Dc offsets - The primary contributors to the dc offset problems encountered by field teams have been unstable weather conditions which have caused unbalance and drift in the phototube amplifiers. The drift is produced both by the galvanometer suspensions and the mechanical linkages in these units.

d. Tape system noise - Tape system noise has been a problem to an average of 18 percent of all field teams. Only 0.1 percent of these noise problems has resulted in rendering the seismic data unusable. The primary cause of tape system noise is faulty tape transport bearings.

7. EQUIPMENT MODIFICATIONS

7.1 GENERAL

This section describes the modifications performed on the LRSM instrumentation to improve system reliability. The special modifications performed on the vans assigned to LASA and the Tonto Forest array study are also reviewed.

7.2 SEISMOMETER ACCESSORIES

One of the problems encountered in the operation of a long-period seismograph system is the time required to establish thermal equilibrium in the seismometer vaults after maintenance or adjustment of the instruments. During the stabilization process, the free period and mass position of a seismometer is apt to vary considerably. Remote free-period and mass-position adjustment units were designed for the seismometers to allow the operator to correct the seismometer parameters from the instrument van.

Difficulty in setting up the mass position monitor assemblies on the long-period seismometers led to the design and installation of an improved aperture

plate on these assemblies. Screw-type adjustments for positioning the apertures between the light source and the photocell bridge allow the operator to center and balance the bridge. A light shield was incorporated in the modification to eliminate the effects of ambient light. Figure 26 shows a long-period horizontal seismometer with the period adjust assembly and the mass position assembly in place. Figure 27 shows a closeup view of the modification on a long-period horizontal seismometer.

7.3 SEISMOMETER VAULTS

Variations in barometric pressure have been established to be a major source of noise in the long-period system. New one-piece seismometer vaults have been designed and will provide more positive sealing. These vaults are replacing the half-shell vaults whenever a mobile observatory moves to a new site location. A further discussion of these vaults is contained in 5.2.4. Manometers and pneumatic couplings are supplied to all field teams to conduct pressure tests on the vaults as soon as possible after they are installed.

Convection currents inside the vaults are believed to be a cause of noise and spiking on the long-period seismographs. Experimental vault lid heaters have been installed in the long-period vaults at Kanab, Utah, (KN-UT) and will be evaluated during the summer of 1966. The heaters consist of loops of resistance wire encased in a rubber pad which is bonded to the underside of the vault lid. They are expected to afford more even heat distribution and greater stratification of air in the vault than the light bulbs previously employed.

7.4 DATA LINES

The data control circuit of the long-period Line Termination Module, Model 8979, has been modified by the installation of hermetically sealed potentiometers and switches. These components are expected to produce a significant improvement in the quality of the long-period data.

Precision 10-turn wire-wound potentiometers were installed in the short-period Line Termination Modules, Model 5874, to provide an accurate, reliable means of maintaining the short-period seismometer damping.

One LRSM field team (SN-AZ) was equipped with an experimental multi-conductor cable system. The system provides 20-conductor cable and multi-terminal connectors on all field wiring to reduce the time required to move a field site. The ac circuitry is isolated from the data and control circuits by use of spiral-four and separate protector boxes. An evaluation of this cable system is described in 4.4.2 of this report.

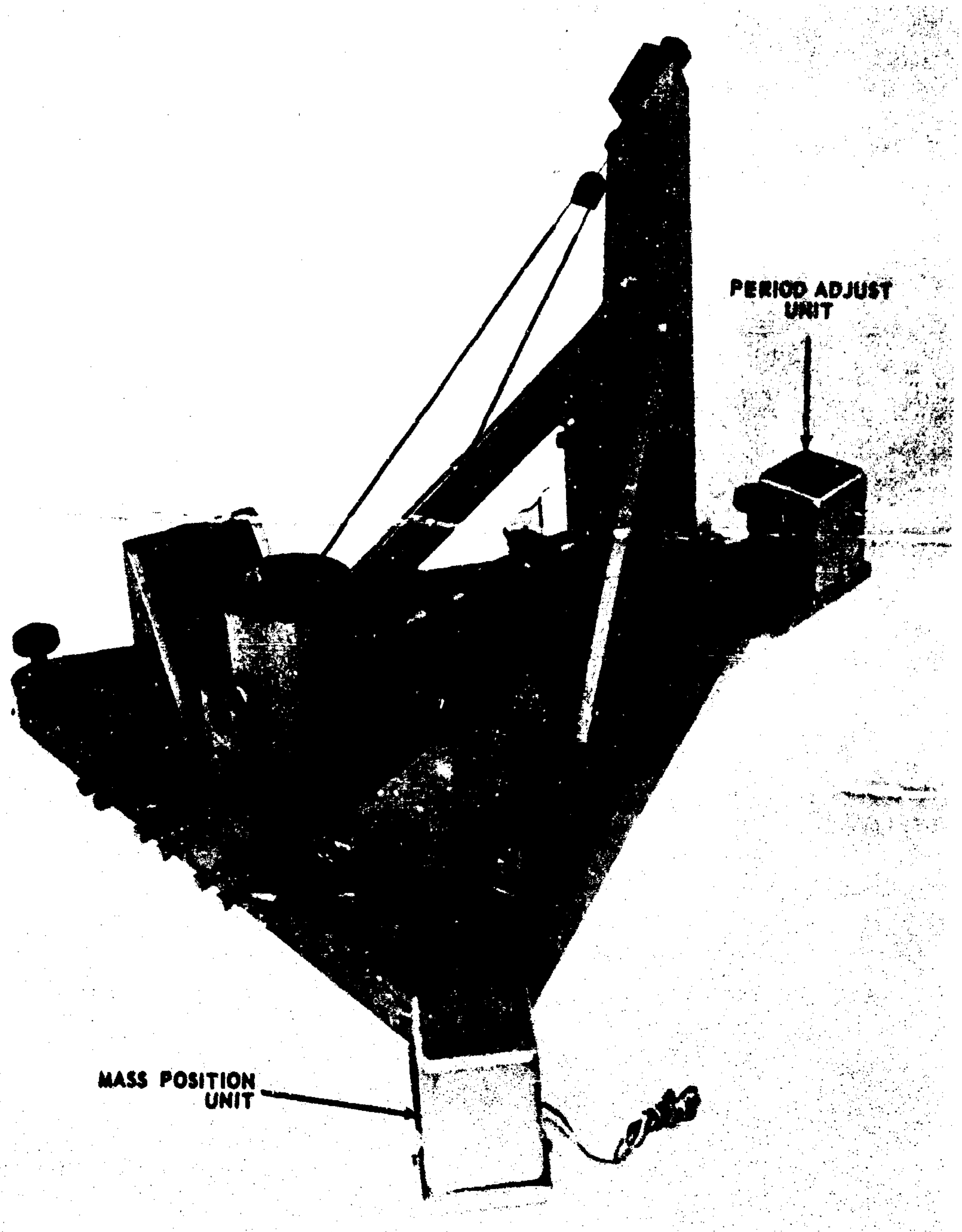

Figure 26. Two remote adjustment units installed on a long-period seismometer

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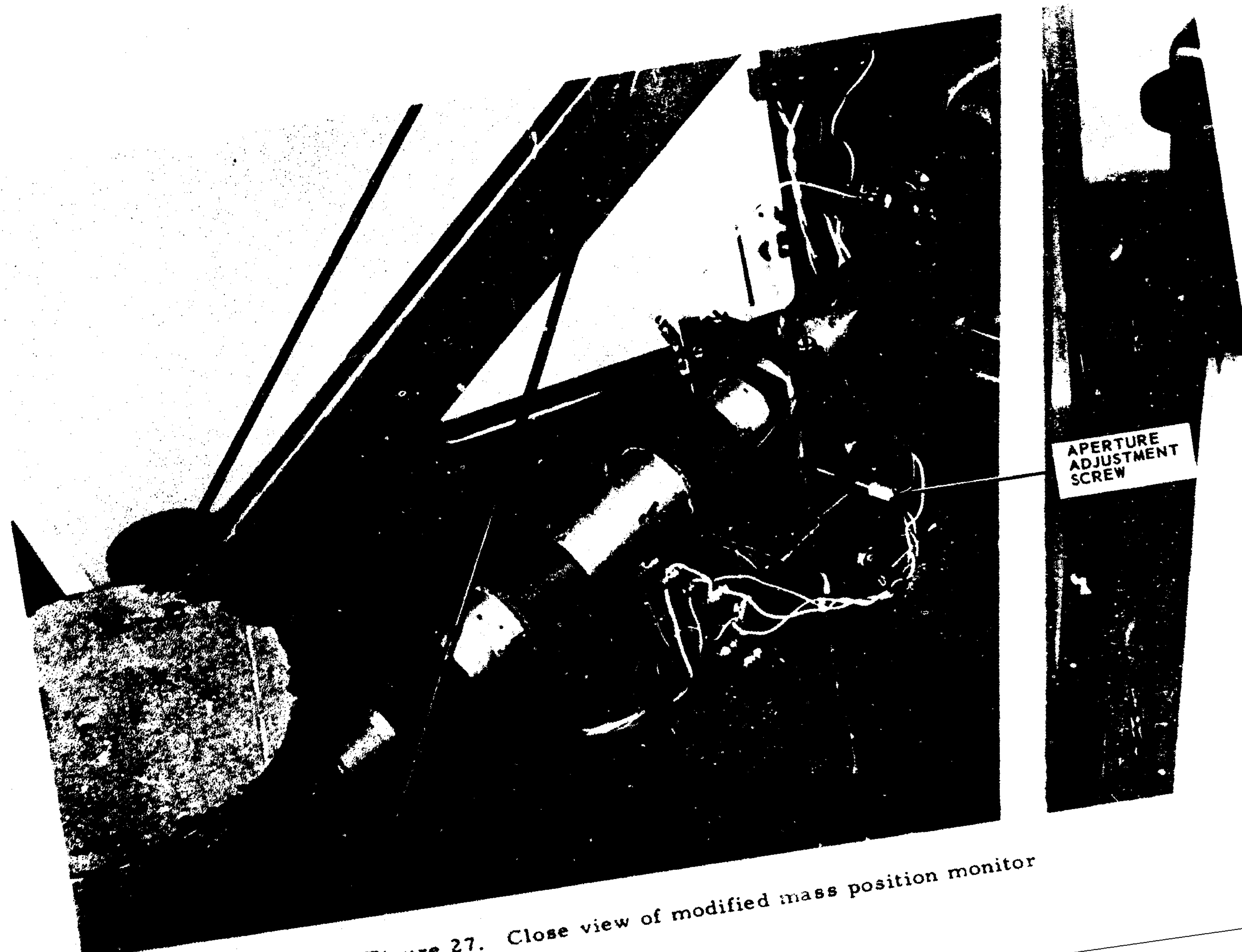

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Figure 27. Close view of modified mass position monitor

7.5 LIGHTNING PROTECTION

To afford greater protection from lightning, two LRSM observatories (AX2AL and JP-AT) have been equipped with a prototype lightning protection system. This system employs gas diodes as the high-voltage protective device and fuses for high-current protection. When a high potential is applied to the transmission lines, the gas in the diodes ionizes and short circuits both sides of the transmission line to ground until the voltage is removed. The diodes are housed in weatherproof boxes and are mounted in the vault area, on the PTA shelter, and on the instrument van. Spiral-four cables were cut to length and hocks were spliced on the cut cable for all cables except the unamplified data cables. All hocks were color-coded to further facilitate setting up the sites. Figure 28 shows the station protector mounted on an instrument van. Figure 29 shows the vault protectors mounted in the vault area. A further description, encompassing the evaluation of the prototype lightning protection system is contained in 4.5.2.

7.6 POWER SUPPLIES

No modifications to the phototube amplifiers were made during the report period; however, precision 10-turn wire-wound potentiometers were installed in the long-period Power Supplies, Model 4304. These potentiometers were installed to supply a more vernier control of the electrical balance of the band-pass filter and output amplifier.

7.7 RECORDERS

7.7.1 Magnetic Tape

The tape supply motors on the Ampex tape transports were replaced with a viscous tape supply unit. The electric motors which provided holdback tension on the tape were driven from the GR voltage regulator and were subject to transient voltage fluctuations. These fluctuations resulted in torque variations in the motor and caused the tape tension to vary widely. To eliminate this problem, a viscous tape supply unit was designed to replace these torque motors. The purpose of this unit was to provide a constant holdback torque to the tape supply reel to isolate the tape from the noise generated by line voltage fluctuations. The viscous tape supply unit uses Dow Corning Type DC-200 silicone fluid as the braking medium. A reel clutch is provided to disengage the viscous tape supply unit for operation of the tape transport in the fast forward mode. The viscous tape supply unit is shown in figure 30.

One problem experienced with the viscous supply unit has been damage to the clutch shaft during shipment. This shaft was originally machined from stainless steel which was too soft to withstand the forces to which it was subjected

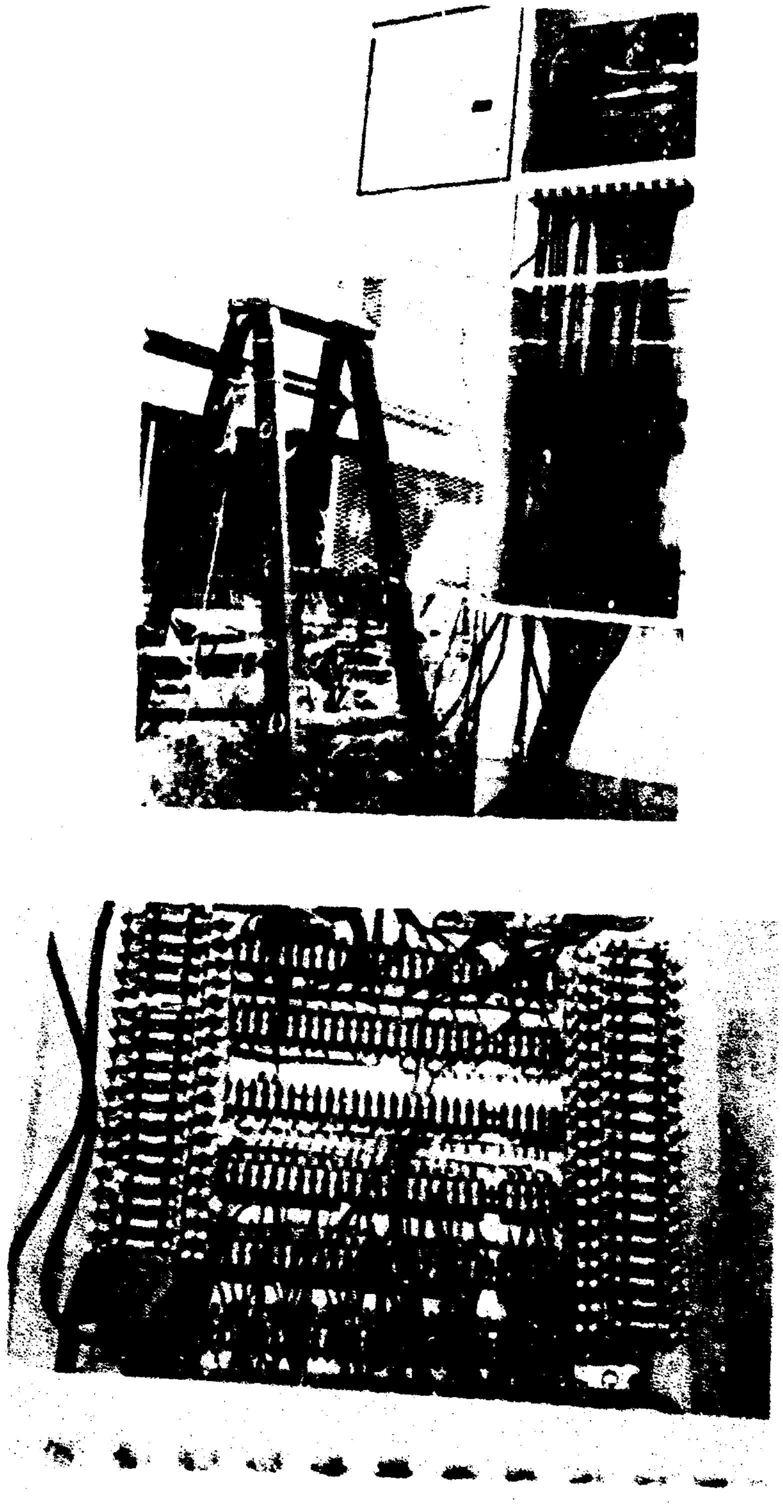

Figure 28. Diode protector mounted on instrument van

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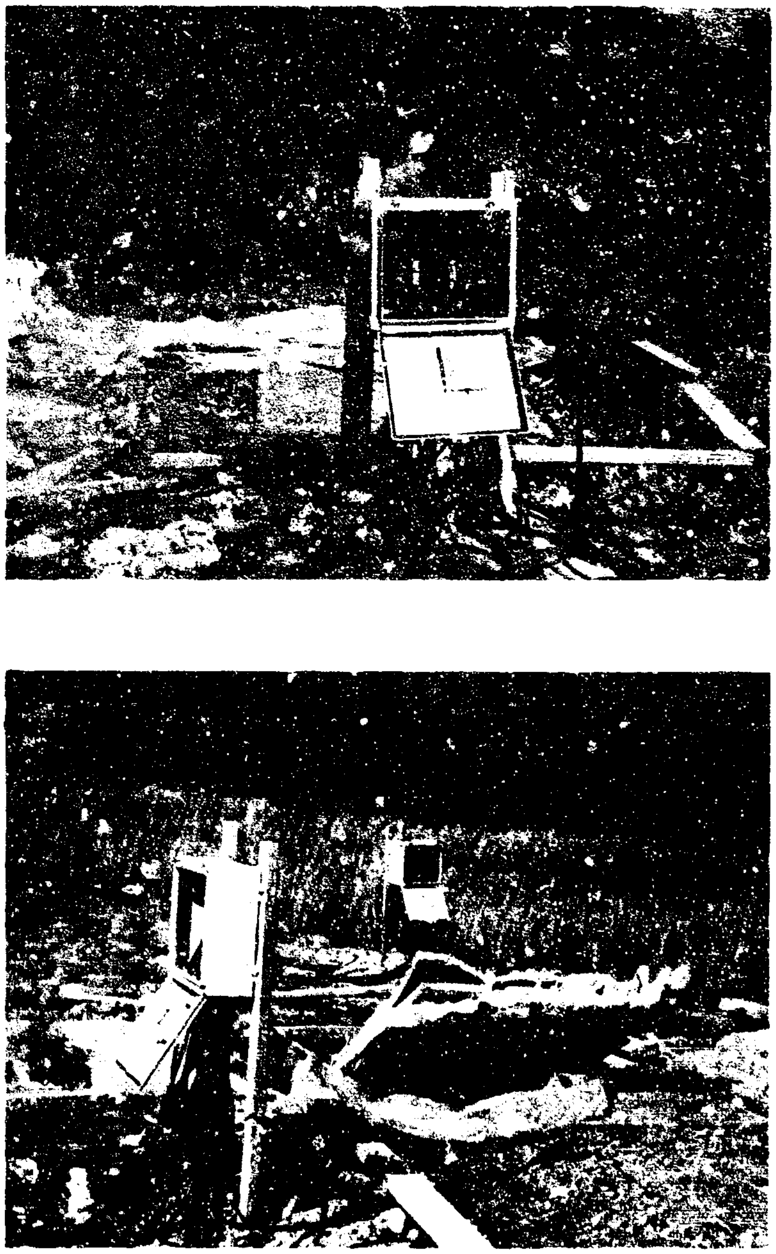

Figure 29. Vault diode protectors

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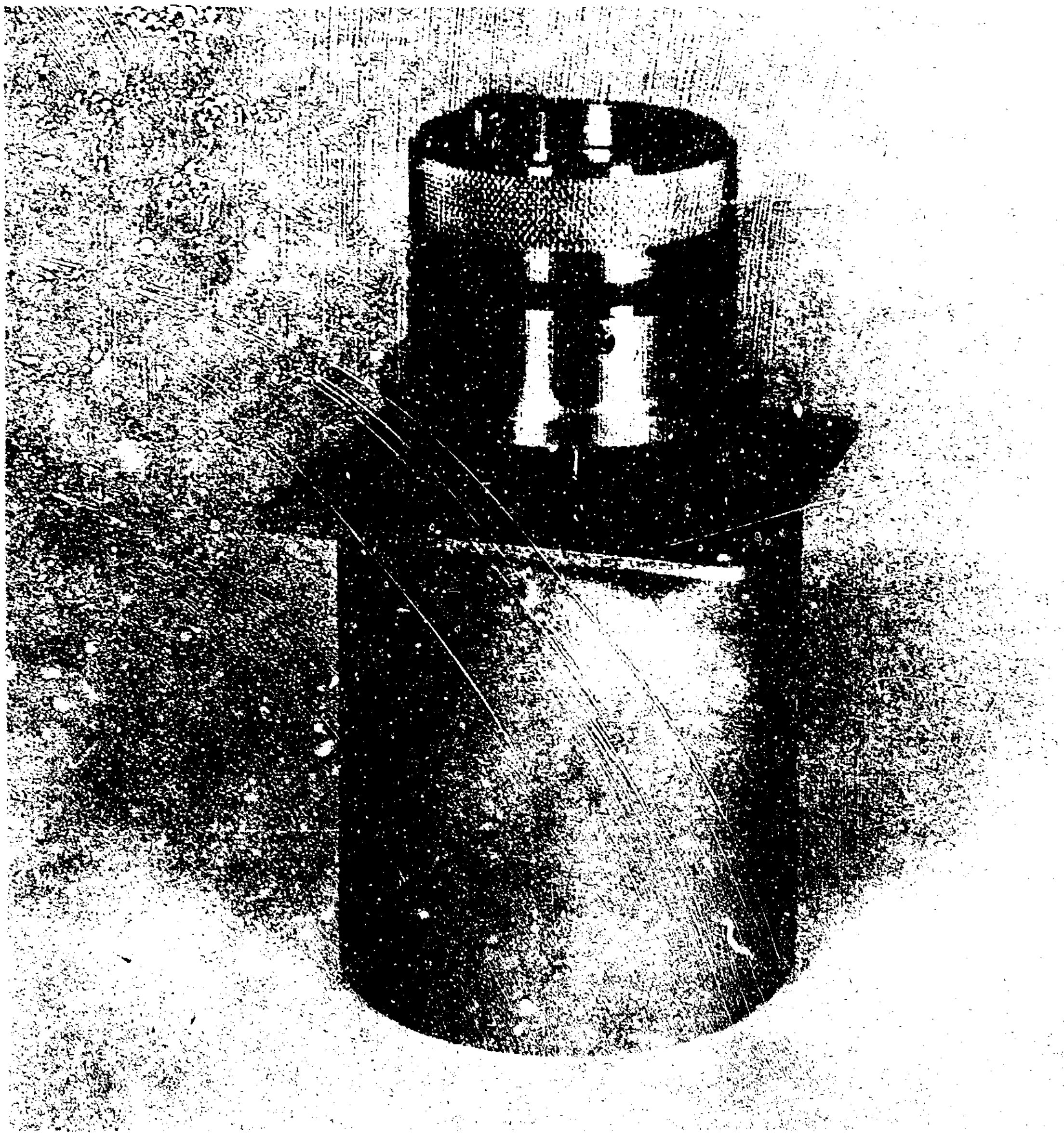

Figure 30. Viscous tape supply unit

G 1744

in shipping. A shaft of heat treated #4140 steel has been designed and is presently being manufactured. These shafts will be installed as soon as they are completed.

7.7.2 Film

No modifications were made to the 35 mm film recorder.

The Develocorder date timers were modified to increase the reliability of the firing circuitry. A new date-timer assembly was developed which uses a low voltage lamp as a flasher instead of the high voltage flash tube. The lamp is the plug-in type and is easy to replace. These modified units have operated without failure.

7.8 SPECIAL MODIFICATIONS FOR LASA

Extensive modifications were made to the two LRSM observatories participating in the LASA program in Montana. Two banks of operational amplifiers and their associated plug-in printed circuit boards were installed to provide isolation between the telemetry equipment and the Ampex magnetic-tape recorders. Figure 31 shows one bank of these operational amplifiers. Five patch panels and associated patch cords were installed to provide signal selection for summation and recording. Two 20-channel Develocorders were installed in the vans to record array data. A Develocorder junction unit was installed for recording WWV and anemometer data on both Develocorders. The station protector was modified to provide an additional 40 input circuit. The Belden 8422 data cables in the van were replaced with Belden 8451 cable (miniature two-conductor with foil shielding).

Forty additional data control modules were installed for array data circuits.

An additional rack was installed to the left of the Ampex magnetic-tape recorder to mount the operational amplifier trays, the additional data control modules and the other equipment required. The storage room at the rear of the van was converted into a darkroom, and the long-period 35 mm film recorder was moved to this room. The short-period 35 mm film recorder was taken out of service to provide space for two Develocorders in the darkroom. Installations outside the instrument van followed normal LRSM procedures except that the field cabling (spiral-four) was buried to a nominal depth of 12 in. as a protective measure against traffic.

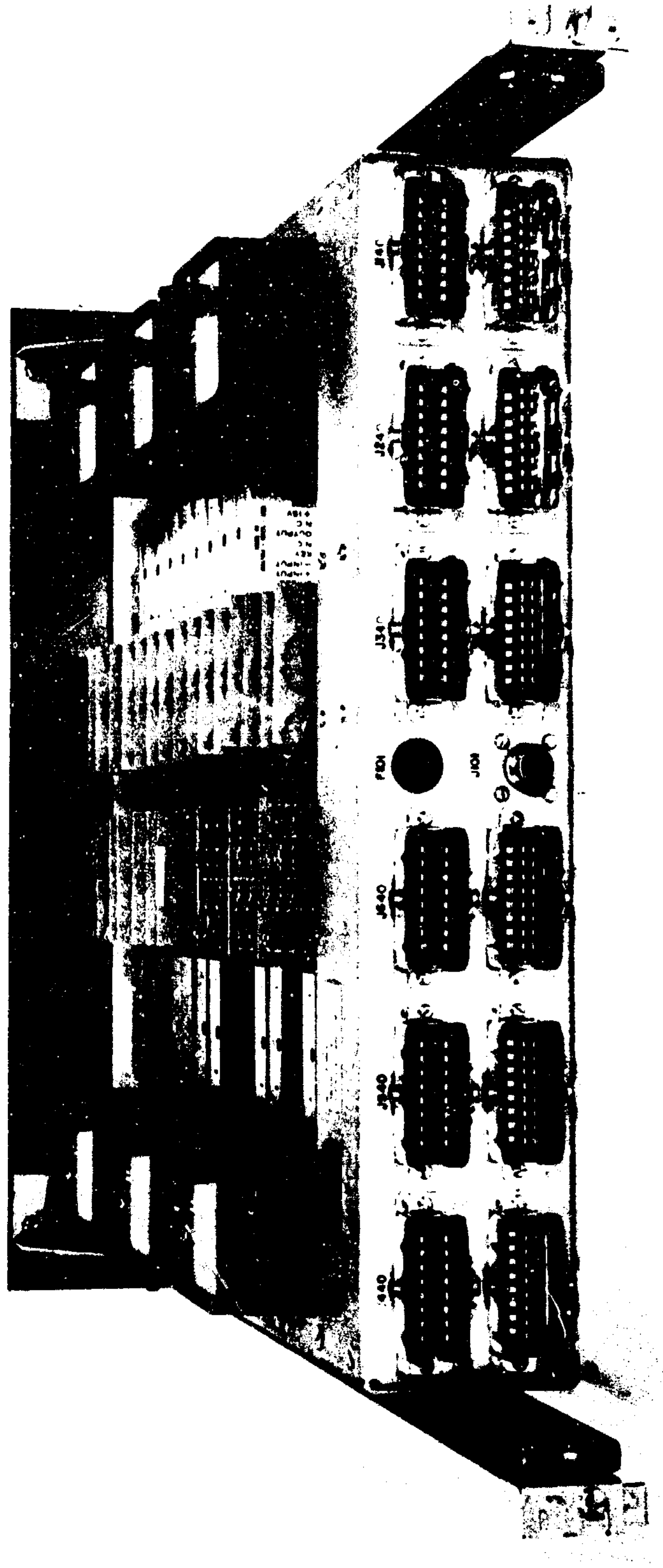

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Figure 31. Rear view of operational amplifier tray

7.9 SPECIAL MODIFICATIONS FOR THE TFSO EXTENDED ARRAY

The modifications discussed herein are limited to the area of responsibility assigned to the LRSM program. An additional Emcor rack was installed in each recording van. All PTA's were operated with balanced outputs and were isolated from the tape recorders by operational amplifiers. Voltage controlled oscillators (VCO's), power supplies, line drivers, rack adapters, and line driving amplifiers were purchased from Astrodata and installed in the vans. VCO control units were installed to provide for calibrating the standard modulation channels and to provide lightning protection for the modulation equipment. VCO gain control units were installed to provide attenuation adjustment for each channel. Line isolators were installed to provide surge protection and transformer coupling. VCO calibrators and frequency meters were installed to apply and monitor calibration signals.

Two of the observatories participating in this TFO study operated seven-element, short-period, vertical arrays. These teams were equipped with summation control units and line switching units in addition to the modulation equipment mentioned above. Loading coils were installed every quarter mile in the 11 miles of spiral-four transmission line from the Sunflower, Arizona (SN-AZ) site to the telephone circuit. This resulted in a 15 dB increase in signal level. Figure 32 shows the instrument van interior of one of the array teams. The additional rack used to house the telemetry and summation equipment is shown in the foreground.

7.10 POWER EQUIPMENT

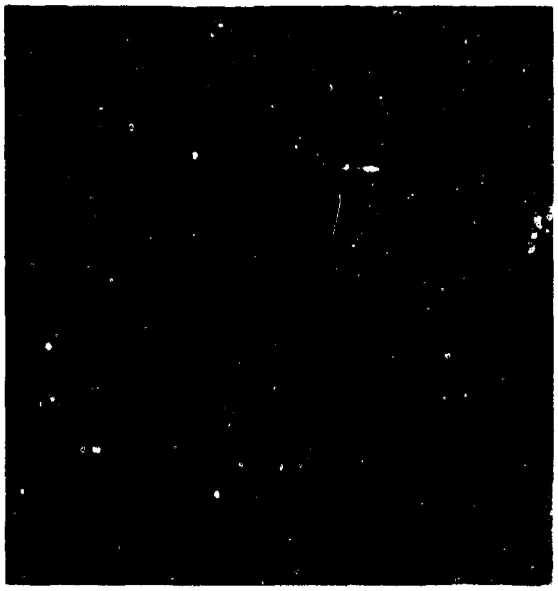
7.10.1 Inverter, Model 9220

Inverters were installed in all vans equipped with modified Model 5400 timing systems, in order to provide a more reliable source of frequency-regulated secondary power. The 9220 inverter is operated continuously and its output is used only when the primary power from the timing system fails. A primary power failure automatically switches the system to secondary frequency-regulated power.

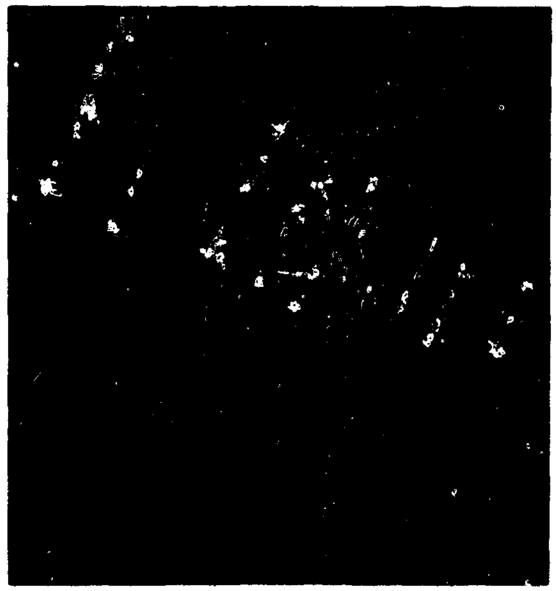
7.11 CALIBRATION CIRCUITS

7.11.1 Function Generator, Hewlett-Packard Model 202A

The single-turn dc balance potentiometer in the function generator was replaced by a 10-turn, wire-wound potentiometer to reduce the sensitivity of this adjustment.



INSTRUMENT RACK AT
A TFSO ARRAY SITE



INSTRUMENT RACK AT
A TFSO STANDARD SITE

Figure 32. Interior view of two TFSO experiment instrument vans

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7.11.2 Fiducial Control Unit, Model 17086

An investigation into the cause of excessive crosstalk in the long-period data circuits revealed the problem to be in the fiducial control unit. This unit was modified by the replacement of three resistors to reduce the crosstalk to a minimum while maintaining a usable fiducial.

7.12 TIMING SYSTEMS

No modifications were made to the Timing Systems, Model 5400-M2 and Model 5400A-M2, during the report period.

8. DATA PROCESSING

8.1 GENERAL

The progress of two groups is reviewed in the following paragraphs. The Special Presentations group has continued to process magnetic-tape data into a variety of formats. Events selected by the Project Officer were composited on magnetic tape for quick recovery for special studies. Several new instruments were integrated into the data processing system, including a subsystem for the playback of portable systems data onto 35 mm film. The Data Processing group has the responsibility of analyzing seismic data. The compilation of the 10-station seismological bulletin was made more efficient and accurate through the use of the Automated Bulletin Process (ABP) and a digital computer.

8.2 SEISMOLOGICAL BULLETIN

An important and continuing data processing function within the LRSM program is the analysis of data recorded by selected LRSM mobile seismological stations. These data are correlated with epicenters reported by United States Coast and Geodetic Survey (USC&GS), and published in a monthly seismological bulletin containing the data from the selected stations. The bulletin is intended to be an aid to VELA-Uniform participants and other interested organizations in determining the extent of the earthquake data contained in the LRSM recordings. During this report period, 27 monthly seismological bulletins were published. From August 1963 through February 1965, two monthly seismological bulletins were published. One bulletin contained data from stations located in the United States or Canada. The second monthly bulletin contained processed data from one mobile seismological station in each of the following countries: Bolivia, Norway, and West Germany. After February 1965, the three-station bulletin was discontinued and during the remaining report period,

one 10-station LRSM seismological bulletin was published each month. Both seismological bulletins follow identical data presentation formats.

8.2.1 Bulletin Content

Each bulletin contains the following:

a. Data on all phases that have been associated with epicenters reported by the USC&GS;

b. Data on epicenters listed in the bulletin as reported by the USC&GS;

c. Arrival time, period, amplitude, and distance for phases not associated with USC&GS epicenters.

Table 4 contains a review of the 27 months of processed data categorized as follows: epicenters received from USC&GS, percentage of USC&GS events recorded by the bulletin stations, number of associated and unassociated phases recorded, and the total number of phases processed.

8.2.2 Bulletin Stations

Table 5 is a list of LRSM seismological observatories used to compile the bulletins published during this report period. The locations of these stations are shown in figures 33 and 34.

8.2.3 Computer Techniques

Three different high-speed data processing systems were used to process the bulletin data during this report period. The first system was developed for the Control Data Corporation's Model 160-A digital computer. The second system was developed for the Control Data Corporation's Model 3100 digital computer. The system now being used utilizes the Automated Bulletin Processing program available at the Seismic Data Library (SDL) in Alexandria, Virginia, and the Model 3100 computer at the Geotech facilities in Garland, Texas. These three systems are described in the paragraphs which follow.

a. 160-A Data Processing System - After completion of record analysis and phase identification, a series of nine FORTRAN programs were used to sort the raw data, calculate distances, azimuths, travel-time residuals, ground motion, magnitudes, and quality-control the data. The computer time required to process one bulletin was approximately 10 hours.

b. 3100 Data Processing System - The nine FORTRAN programs used on the 160-A computer were modified for use with the 3100 computer. Four programs, BUZAR, DELTAZ, PREPARE, and JB TIMES, were merged to form two more efficient programs, BUZAZ and JB TIMES, which reduced the

Table 4. Data compiled in LRSM and overseas seismological bulletins from August 1963 through October 1965

Year	Month	USC&GS epicenters	Percent of events recorded	No. of associated phases	No. of un-associated phases	Total No. phases
1963	August	310	75	2420	1045	3465
	Sept	433	71	2217	715	2932
	Oct	713	53	2397	663	3060
	Nov	390	68	1860	730	2590
	Dec	381	59	1817	595	2412
1964	Jan	344	63	1708	496	2204
	Feb	326	83	963	453	1416
	Mar	642	71	2977	1277	4254
	April	591	75	3777	845	4622
	May	393	63	2350	654	3004
	June	342	73	2063	821	2884
	July	391	74	2857	907	3764
	Aug	350	70	2480	1128	3608
	Sept	338	71	2541	1278	3819
	Oct	361	69	2511	1054	3565
	Nov	346	67	2203	915	3118
	Dec	303	74	2339	887	3226
1965	Jan	358	78	2028	860	2888
	Feb	1030	83	5453	1655	7108
	Mar	710	77	4184	1345	5529
	April	525	80	4133	1820	5953
	May	416	77	2554	1121	3675
	June	477	79	3218	1400	4618
	July	420	77	2723	1171	3894
	Aug	531	67	3316	794	4110
	Sept	396	69	2440	1045	3485
	Oct	398	67	2185	1171	3356
TOTALS	27 months	12,215	Avg 72	71,714	26,845	98,559

Table 5. LRSM seismological observatories used to compile seismological bulletins published during 1 July 1964 through 31 March 1966

STATION DESIGNATOR

AD-IS	Adak, Aleutian Islands
BL-WV	Beckley, West Virginia
BR-PA	Berlin, Pennsylvania
DH-NY	Delhi, New York
DR-CO	Durango, Colorado
FN-WV	Franklin, West Virginia
* GG-GR	Grafenberg, West Germany
GV-TX	Grapevine, Texas
HW-IS	Hawaii Island
HN-ME	Houlton, Maine
HY-MA	Hysham, Montana
JE-LA	Jena, Louisiana
JR-AZ	Jerome, Arizona
KN-UT	Kanab, Utah
* LZ-BV	LaPaz, Bolivia
LC-NM	Las Cruces, New Mexico
LV-LA	Liddieville, Louisiana
MN-NV	Mina, Nevada
MV-CL	Marysville, California
NP-NT	Mould Bay, Northwest Territory
* OO-NW	Oslo, Norway
RK-ON	Red Lake, Ontario
SV2QB	Schefferville, Quebec

* Station data used in the three-station seismological bulletin

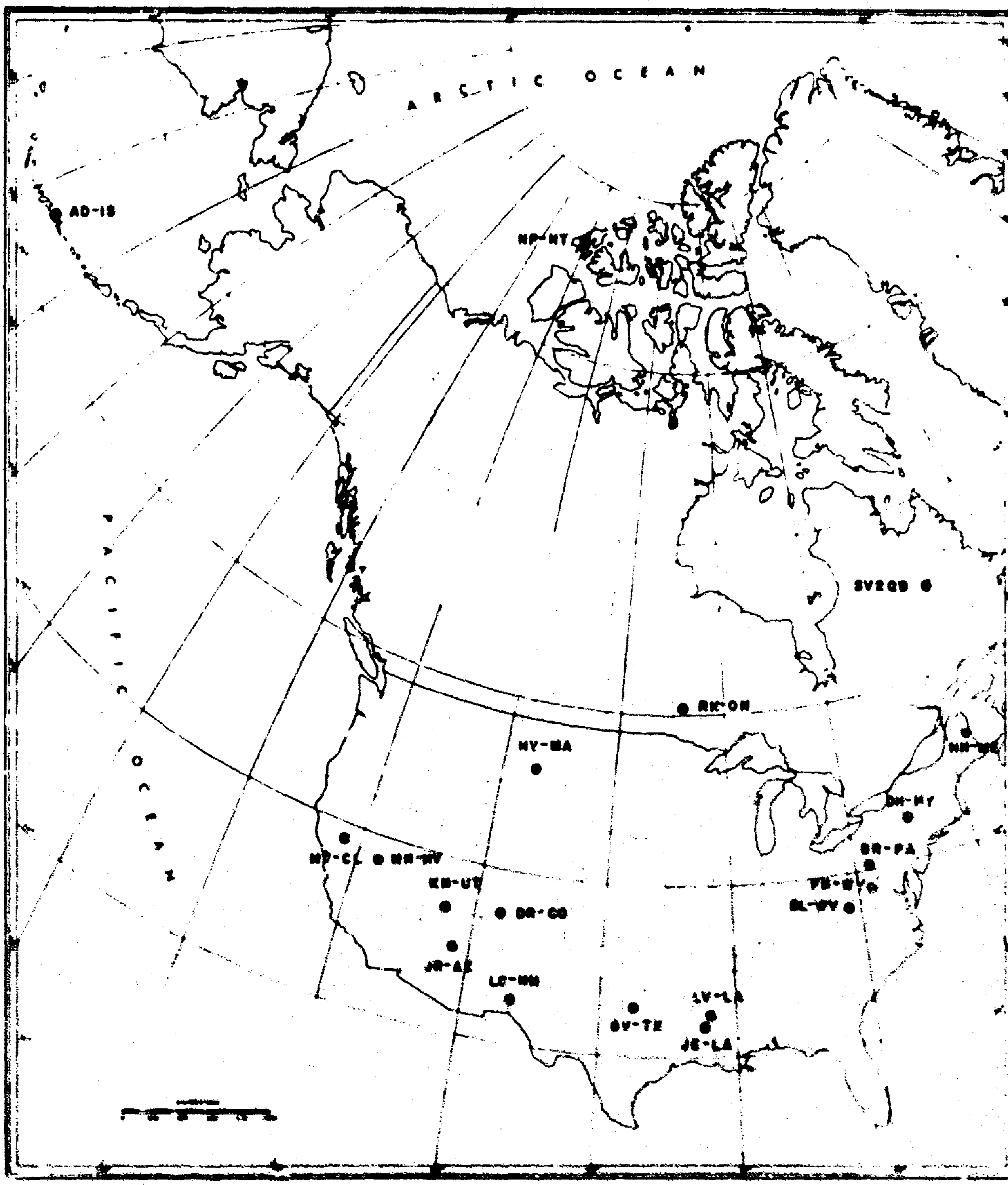

Figure 33. LRSM seismological bulletin sites

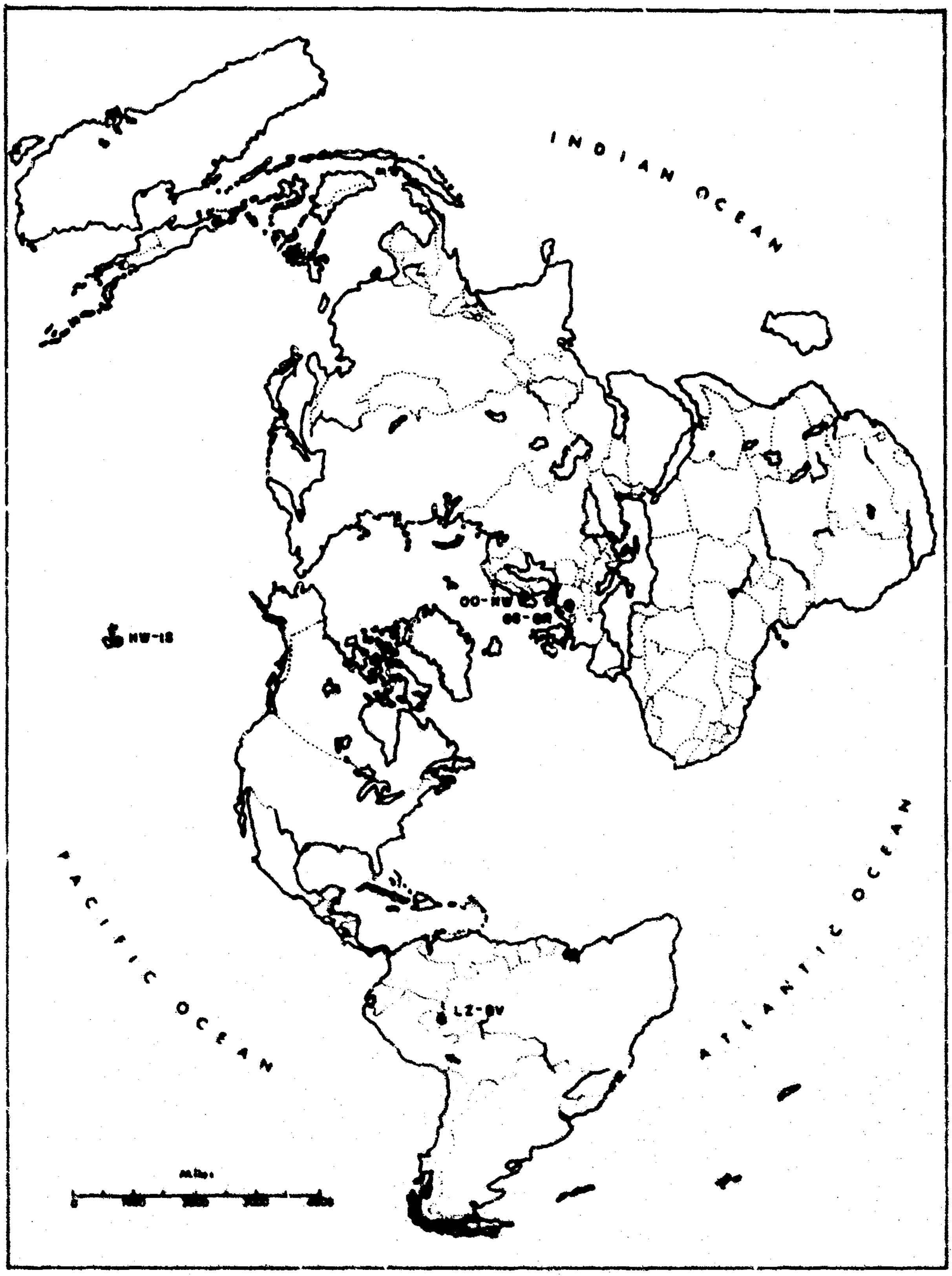

Figure 34. Overseas seismological bulletin sites

operating time. The computer time required to process one bulletin is approximately 5 hours.

c. Automated Bulletin Processing (ABP) - A program, Automated Bulletin Processing (ABP), being used at SDL has been made available to LRSM. After preliminary analysis, the raw data is shipped to SDL and the ABP program associates the data with USC&GS epicenters, makes phase identifications, calculates station-to-epicenter distances and azimuths, travel-time residuals, ground motion, magnitudes, and sorts the data in accordance with the LRSM bulletin format. The program has been thoroughly evaluated by using similar data and comparing the output of the ABP program with manual analysis performed by trained analysts. Two months of data (November 1964 and May 1965) were compared before the ABP program was incorporated into the LRSM program. The ABP program virtually eliminated the human error factor from bulletin processing, which seemed to be a major problem with the manually produced bulletin. ABP is capable of identifying 23 phases (excluding eL, eLQ, and eLR), whereas approximately 40 phases can be identified manually. However, the phases identified manually which cannot be identified by ABP constitute only 3 percent of the phases identified. Also, approximately 200 man-hours are saved each month because the majority of the phase identifications are being made by the ABP program in place of the analysts. This time is being used for completing special studies and investigating ABP association discrepancies.

The total computer time now required to process one bulletin is approximately 3-1/2 hours. Figure 35 shows a flow diagram of the data processing system now in use. The October 1965 bulletin was the first bulletin which was compiled utilizing the ABP program.

8.3 PROCESSING MAGNETIC-TAPE DATA

The Special Presentations group is primarily concerned with the processing of magnetic-tape data. These data are transcribed in various forms to meet the requirements of numerous routine and special studies. Data are reproduced on photographic paper and 16 mm, 35 mm, and 8-7/8 inch photographic film. By controlling both the tape and photographic recorder speeds, a wide range of playback speeds are possible. During this 21-month report period, over 5,500 visual recordings were produced from magnetic tape. In addition, the group continued to prepare composite magnetic tapes of events selected for study by the Project Officer. Seventy-seven such composites were completed. The equipment consoles and the area used by the Special Presentations group are shown in figure 36. A complete listing of the equipment utilized by this group is contained in appendix 4. New methods of data presentation are continually under investigation to improve existing formats and create new data formats.

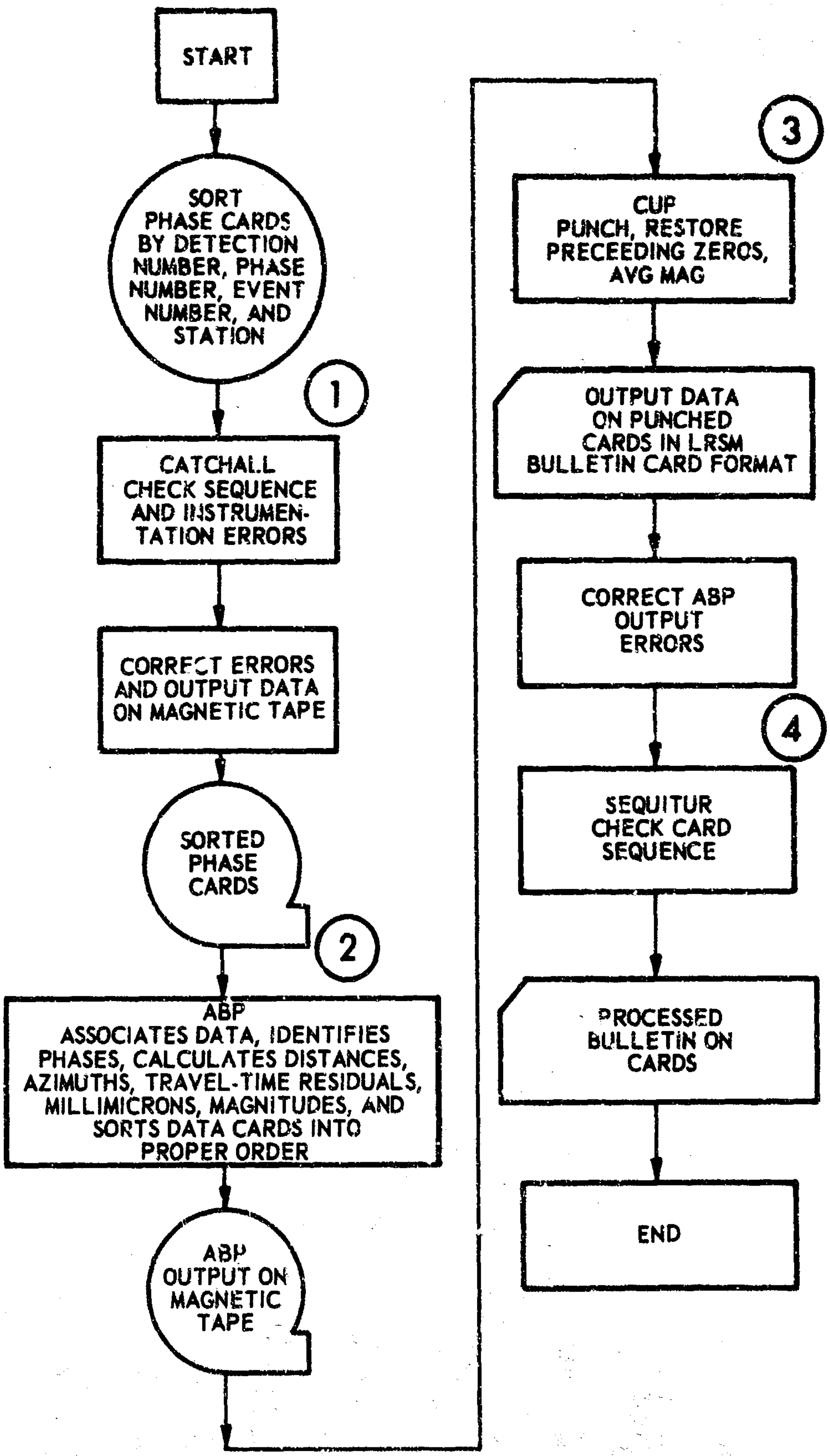

Figure 35. ABP LRSM bulletin processing system G 1747

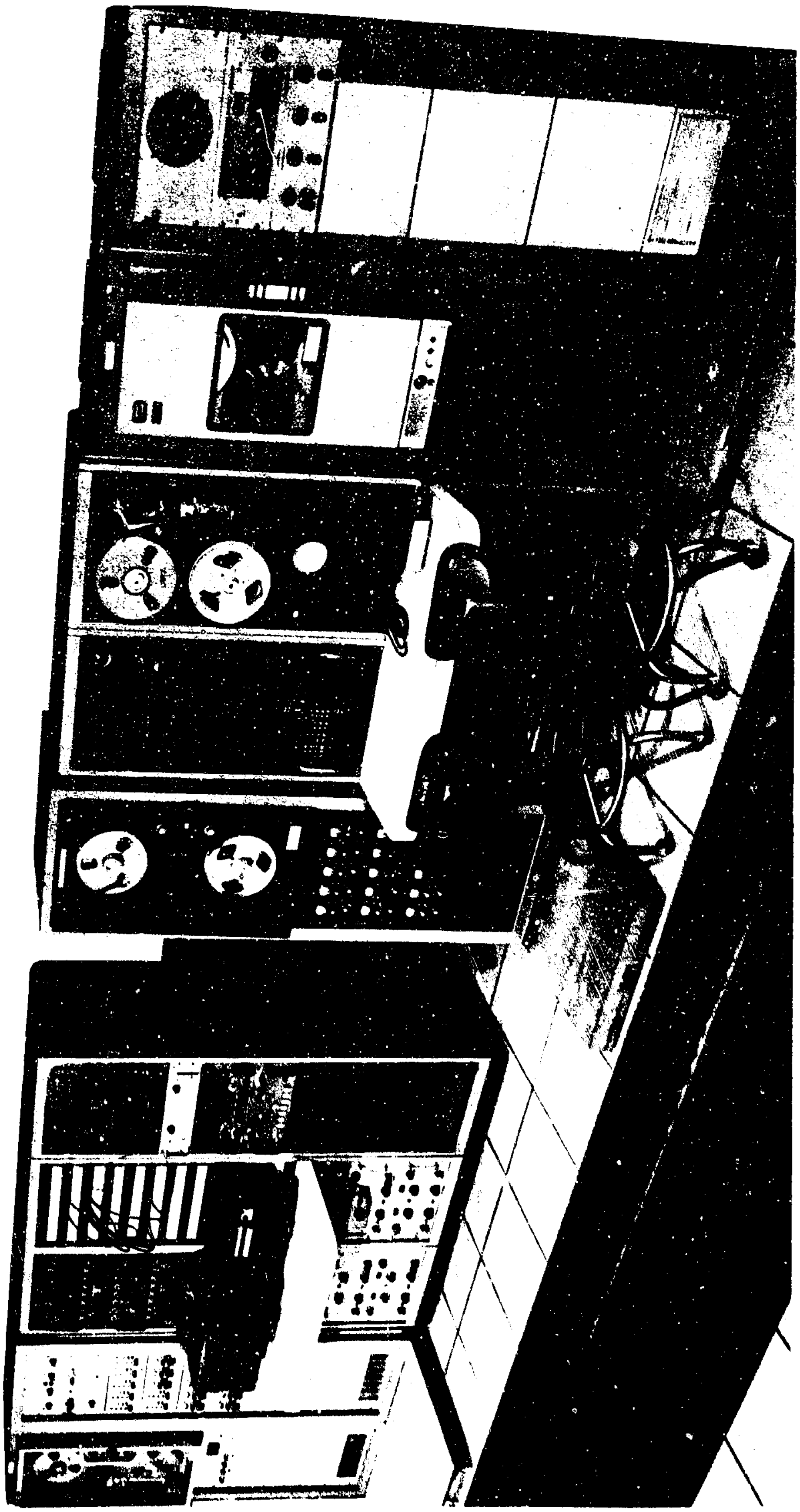

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Figure 36. Special presentations system

8.3.1 Auxiliary Equipment

During this report period, several new instruments were added to the special presentations data processing system. A description of these components follows:

a. Eight-channel dc amplifier - This unit (shown in figure 37) is a self-contained, transistorized, 8-channel differential amplifier constructed on standard printed circuit boards. The input impedance is variable from 500 ohms to 100K ohms. The output impedance is less than 50 ohms. This amplifier was developed primarily as a galvanometer driver, but a number of additional applications have been developed. These applications include: impedance matching, signal isolation, and signal inversion.

b. Hyperion tape search unit - The requirement to process data recorded on slow-speed (0.03 ips) recorders produced a need for a rapid tape search technique using Binary Coded Decimal (BCD) time. A Hyperion Tape Search and Generator, Model HI231V-A, was purchased to furnish this capability. This unit controls the LAR-7400 tape transport and by decoding the BCD time records on the tapes, can locate any selected time. It switches the tape transport into the fast-forward or rewind modes for search and to a preselected playback speed for slow search and reproduce. A front view of the tape search unit is shown in figure 38.

c. Playback of portable systems data - One major task of the Special Presentations group is to reproduce all portable systems magnetic-tape data onto 35 mm film. Figure 39 shows a block diagram of the system developed to provide this capability. Figure 40 shows the portable systems data processing system in operation.

The timing channels recorded by portable systems in the field are direct recorded. Reproduce amplifiers and preamplifiers furnished with the tape transports used in the Special Presentations group have not provided adequate fidelity. A preamplifier was developed which incorporated a modified Geotech Model 24779 amplifier. This unit provides excellent fidelity with virtually no waveform modification. One of these preamplifiers has been built for each of the four major tape transports used by the group.

When only BCD time is available on tape, such as in the case of the portable system magnetic tapes, a unit is needed to convert BCD time to a standard time program format. A time program converter was developed and constructed to meet this need. It is a transistorized logic unit which produces 10-second, 5-minute, 30-minute, and 1-hour marks, with zero time correction from BCD time. The BCD carrier can vary from real time (10 cps) to 20 kc without external adjustment. The time program converter is shown in figure 41.

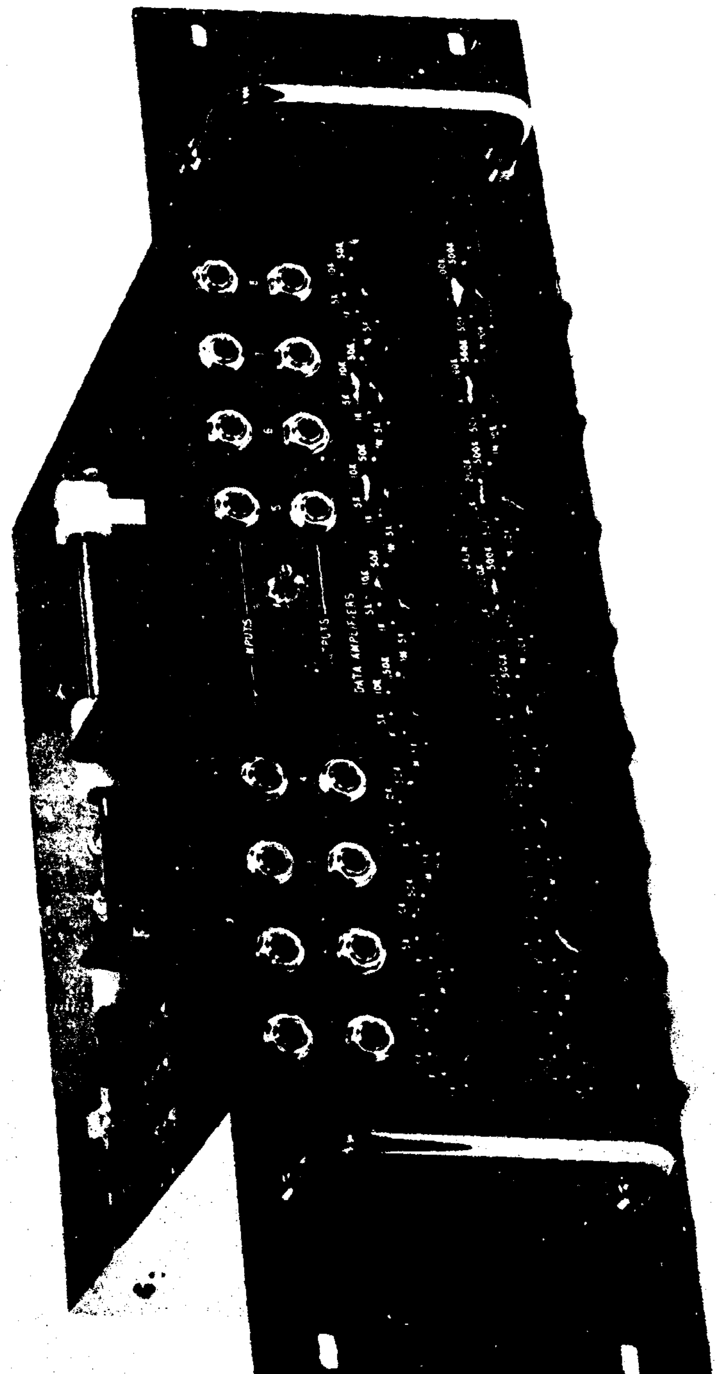

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Figure 37. Eight-channel dc amplifier

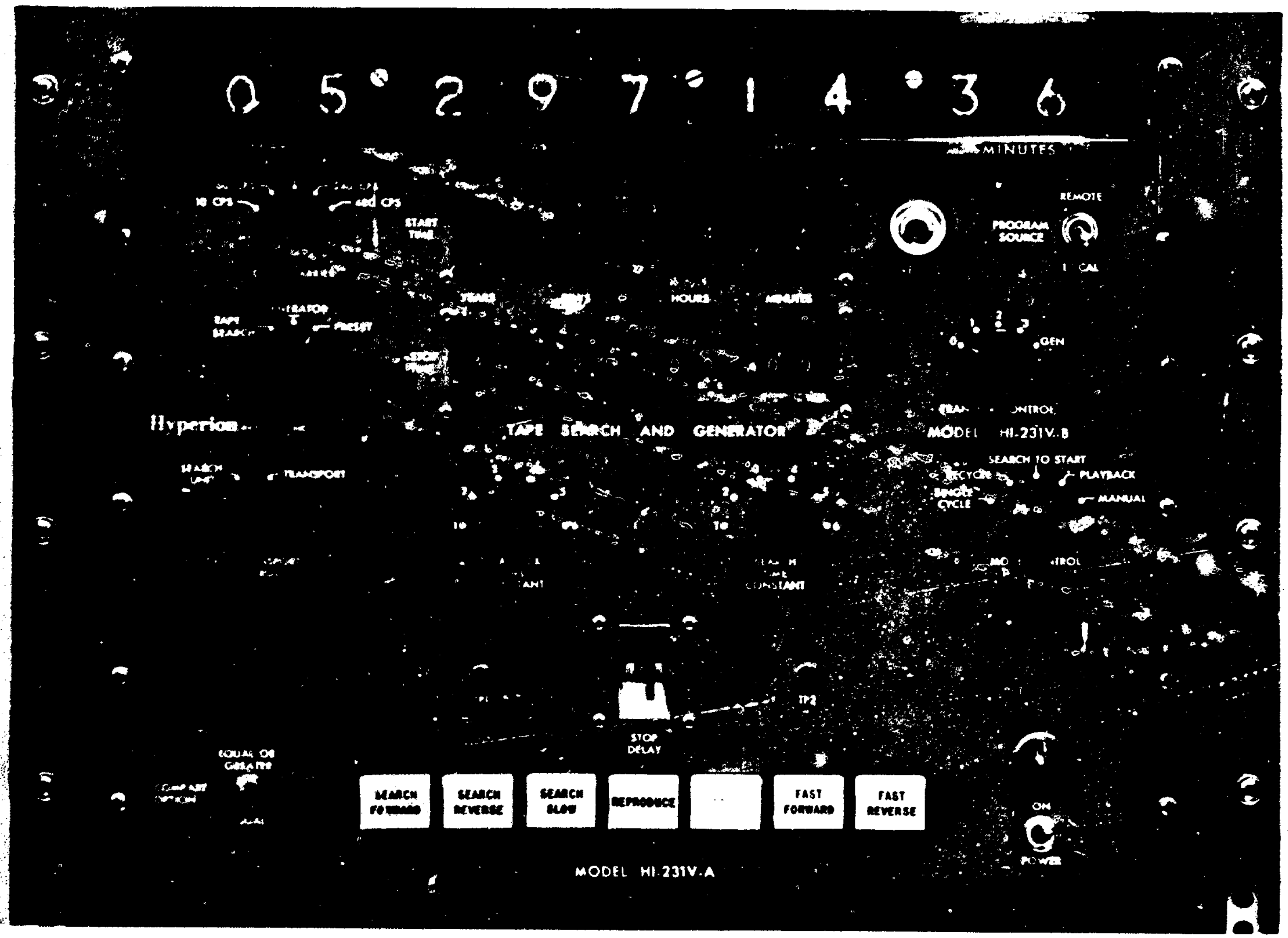

Figure 38. Hyperion tape search and generator, front view

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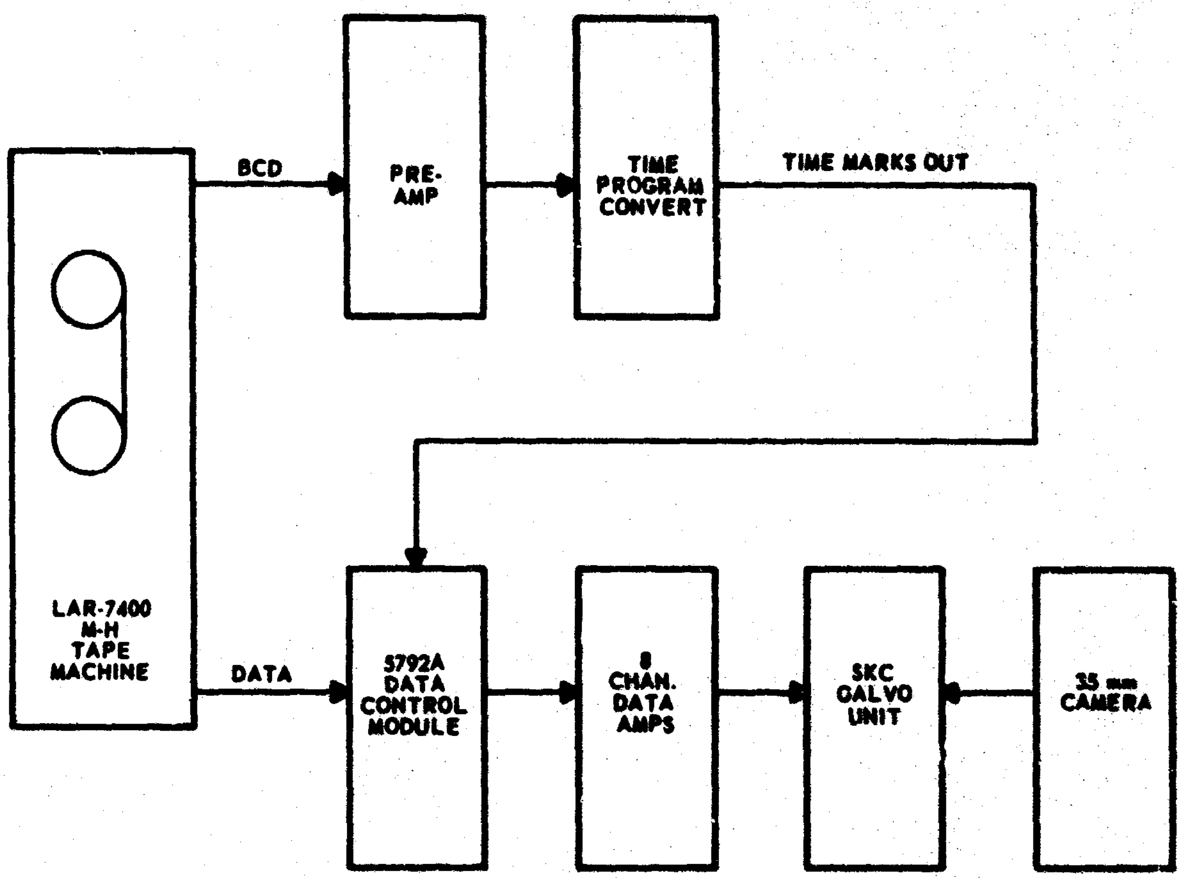

Figure 39. Block diagram of the portable systems playback system

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Figure 40. Portable system's data processing system in operation

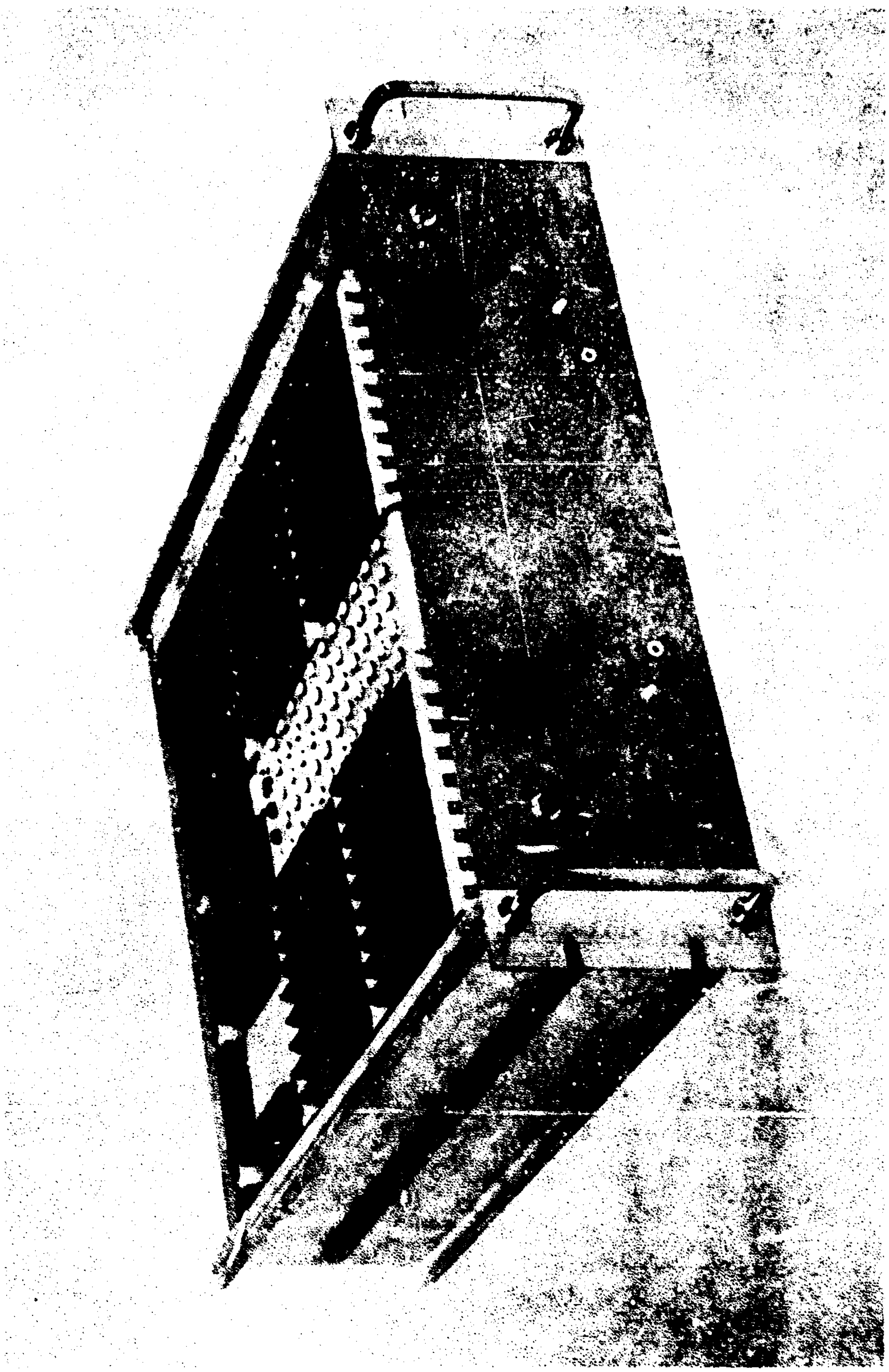

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Figure 41. BCD time program converter

In order to process portable systems data at 1000 times real time, a unit was constructed incorporating eight 5 kc CEC No. 7-361 galvanometers. A mercury vapor lamp is used for a light source. Resolution on 35 mm film at X20 view produces a trace width of 1 mm.

A camera was borrowed from General Atronics Corporation pending receipt of a camera built to Geotech specifications. To this date, 33,000 feet of short-period data film and 4,000 feet of long-period data film have been processed.

d. A-to-D converter and monitor trigger - A unit was developed and built by the Special Presentations group to start the analog-to-digital converter on selected time marks and also to automatically start a remote monitor. The unit is a transistorized logic device that detects time marks and provides start pulses and relay closures.

e. M-H LAR-7400 remote control - It was not possible to locate the playback transport and the A-to-D converter within the same console. A remote control unit was built to operate the tape system transport remotely from the converter unit.

f. Ten-channel attenuator - To process data with the A-to-D converter, an attenuator was needed that properly matched impedances within the system. A 10-channel attenuator was designed and built for this purpose. Careful selections of resistance values produced a 0-to-18 dB attenuator which has 2 dB steps and an accuracy of 2 percent.

g. Ten-channel summation unit - Recent data playout assignments have required that several analog signals be summed. A dual, 10-channel, summing unit was built which gives uniform attenuation and impedance matching with an accuracy of 2 percent.

h. Analog spectrum analyzer - Approximately 570 spectra have been processed for various special studies within the LRSM program. At the present time, the spectrum analyzer is being evaluated for possible modification to improve its operational characteristics.

8.4 SEISMIC NOISE SURVEYS

Noise studies give an indication of the properties of the seismic noise found in a given area. A completed noise survey for a given LRSM site includes: a curve showing cumulative probability distributions of amplitudes; a histogram showing percentage of occurrence of indicated periods; and a noise spectrum curve showing the average noise amplitude in millimicrons, corrected for the system response and plotted as a function of period.

Two hundred seismic noise samples are taken from approximately 2 week's recorded data on a random basis. Selections are made from nighttime and daylight hours, windy days and quiet days. The period of the noise measured is a major factor as the curves are determined for a specific period range (usually the expected range of major earthquake phase arrivals). The period range sampled on the short-period system is 0.3-1.4 seconds; the long-period range is 6-100 seconds. Noise amplitudes are reduced to a common reference by dividing the recorded amplitudes (in mm) by the system magnification at 1.0 second for short-period data and at 25 seconds for long-period data for the noise amplitude versus percentage of occurrence plots.

During this report period, the Data Control group prepared and published 44 LRSM site noise surveys.

8.5 DATA CATALOG

The data catalog is a monthly compilation of all recordings received from the LRSM observatories. The catalog treats the film and magnetic-tape data in separate sections, each arranged in chronological order. Each data channel and data trace is shown individually.

Included in the catalog is a listing of all stations operational during the month, a map showing the location of each of the stations, and the frequency response of the systems being operated.

Automatic data processing has considerably shortened the time required to compile and publish the catalog. Figure 42 shows a typical page from the catalog, which was processed on an IBM printer.

8.6 SHOT REPORTS

In the interim July 1964 through March 1966, two reports were published on events selected by AFTAC, providing the data required by the standard 45-day shot report format. The events reported were HANDCAR and CORDUROY.

9. SPECIAL PROJECTS

9.1 GENERAL

Throughout the contract period covered by this report, several scientific studies were conducted. These projects were initiated when, after a preliminary investigation, the topic appeared promising in terms of producing practical results. Broad categories of investigations completed included: surveys

LRSM DATA CATALOG

OUTAGE TIME – 35 MM FILM											DECEMBER 1965
SITE	LOGS SP	LOGS LP	SPZ	SPR	SPT	RA	LPZ	LPZ-Lo	LPR	LPT	REMARKS
	1 DEC 65										
BE-FL							18-19	18-19			
HN-ME											RECORDING STARTED 0000Z
HV-MA							22-23	22-23			
SI-BC				22-23							RECORDING STARTED 0000Z
GV-TX							16-21	16-21			
RG-SD									10-18		
AP-OK											INOP ENTIRE RUN-SETTING UP
	2 DEC 65										
SV3QB							14-15	14-15			
KN-UT					01-02						
HV-MA							01-04	01-04			
SW-MA							20-21	20-21			
AP-OK											INOP ENTIRE RUN-SETTING UP
	3 DEC 65										
SV3QB							07-15	07-15			
JP-AT							13-19	13-19			
JP-AT							21-00	21-00			
AP-OK											INOP ENTIRE RUN-SETTING UP
	4 DEC 65										
AP-OK											INOP ENTIRE RUN-SETTING UP

Figure 42. Sample playout of the Data Catalog

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of seismological bulletin data; effects of site geology on signal and noise properties, new data processing and calibration techniques; and miscellaneous projects.

9.2 SURVEYS OF SEISMOLOGICAL BULLETIN DATA

a. Amplitude comparison survey (Memorandum Report, 8 January 1965) - Work was completed on a study of the relative signal amplitudes recorded at LRSM bulletin sites. The results confirmed those of a preliminary survey made during August 1963, which showed that in studies comparing signal amplitudes at two sites over a broad magnitude range, a very definite bias can be imposed on the average comparison by the difficulty of recording anomalously low-amplitude signals from low-magnitude events. The study also confirmed previous observations that sites with high seismic background levels tend to record higher amplitude signals.

b. Percentages associated with the detection of long-period surface waves from low-magnitude events (TR 65-68) - A statistical survey of LRSM bulletin data was made to determine the percentage of earthquakes from which long-period surface waves are recorded, as a function of event magnitude. The bases for the percentages were the events located by USC&GS. Detection-versus-magnitude functions were computed for short-period signals and for long-period surface waves from earthquakes at depths less than 75 km. The comparative functions are reproduced in figure 43. A joint distribution of detection percentage versus magnitude and distance was determined for long-period surface waves recorded at LC-NM. For comparison, a similar distribution was computed for a typical moderate-gain site, Marysville, California, (MV-CL).

From these data, it was concluded that the detectability of long-period surface waves decreases continuously and almost linearly with decreasing magnitude, there being no apparent magnitude threshold below which earthquakes do not generate such waves. Another interesting result was the fact that Love motion from an event is virtually never observed without attendant Rayleigh motion, although Rayleigh is very frequently recorded without Love.

c. Relationship between the energies in the short-period and long-period P phases recorded from teleseismic earthquakes (Memorandum Report, 15 June 1965) - This survey attempted to determine, statistically, the general relationship between the energies in the short-period and long-period P phases recorded from earthquakes at teleseismic distances. The data obtained indicated a very broad tendency for the peak energy densities in these two period bands to be equivalent. Further surveys in which greater control is placed on parameters such as event magnitude and depth are expected to give more resolved information about the spectral partition of P-wave energy for earthquakes.

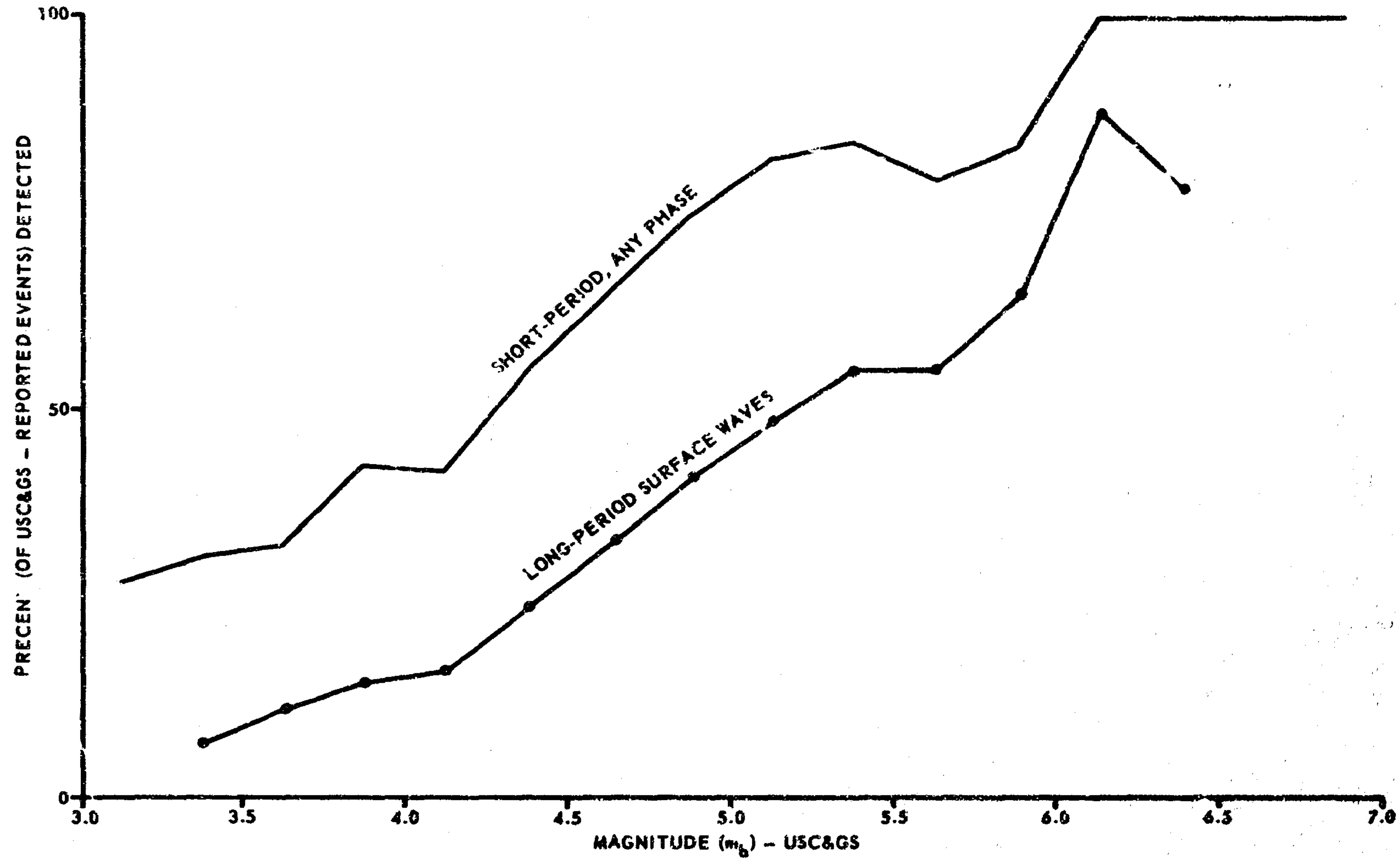

Figure 43. Comparison of short-period and long-period detection functions (February 1963 - July 1964)

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d. Probabilities associated with the detection of long-period body and surface waves from earthquakes and underground detonations (Technical Note 10/66) - A survey was made to assess the comparative chances of detecting short-period and long-period energy from earthquakes, and to determine whether this comparison differs significantly for underground detonations. The earthquake data were taken from LRSM bulletins; explosion data were extracted from 19 LRSM shot reports. For both source types, the study was limited to long-period P, S, and surface waves, and short-period P phases. The basic survey technique was to tabulate percent detection as a joint function of distance and magnitude.

The results indicate that, over all magnitude categories and within the distance range from 0 to 100 degrees, the short-period seismographs at an LRSM installation will detect P waves from about twice as many earthquakes as will be detected on the long-period seismographs via surface waves. This relationship appears to be about the same for underground nuclear detonations. The long-period seismographs at an LRSM installation will record roughly one-tenth the number of P phases that are registered from earthquakes on the short-period instruments. To date, the number of long-period body waves (P and S) detected by the LRSM vans from underground detonations at NTS is surprisingly small (6), an intriguing contrast to the 144 detections that should be expected on the basis of earthquake statistics for the same distances and magnitudes.

9.3 INVESTIGATION OF THE EFFECTS OF SITE GEOLOGY ON SIGNAL AND NOISE PROPERTIES

a. Time-compensated presentations of TFSO extended array data (Memorandum Reports, 16 December 1964 and 1 March 1965) - Composite seismograms for 15 earthquakes were distributed in which the P waves recorded at the 8 LRSM sites surrounding TFSO were visually time-aligned and summed. Each seismogram was fully labeled with the trace magnifications, timing, and hypocenter information. They showed the high similarity of the first few cycles of teleseismic signals at all sites, and were extremely useful in subsequent studies of the TFSO extended array.

b. The effect of crustal structure on teleseismic P-wave travel-time anomalies at the TFSO extended array, Arizona (TR 66-17) - This study compared observed travel times from 33 teleseismic events with computed travel times based on a crustal model resulting from recent seismic-refraction surveys in the TFSO area. It was determined that this crustal model cannot account for the observed travel-time anomalies between stations and that a thorough study of the upper mantle must be made if causal relationships are to be determined.

c. Characteristics of signals recorded from the CORDUROY event by the LRSM portable systems (Memorandum Report, 14 January 1966, and CORDUROY Shot Report, TR 66-43) - The short-period seismographs in these systems were set up along the arc of a circle centered at NTS, each system being situated in a region of distinctly different geological character. The experiment demonstrated the considerable effect that the earth's crust can have on the character and amplitude of a teleseismic P wave. The amplitudes recorded agreed roughly with the "theory of seismic impedance," with one notable exception. The five P waves recorded are shown in figure 44.

d. Study of signal amplitudes at the TFSO extended array (in progress) - A study of the amplitudes of teleseismic signals recorded at the TFSO extended array was begun. The relative amplitudes registered at the 8 LRSM sites will be tabulated for about 30 events, and an attempt will be made to relate the comparative patterns thus found to the geological differences among the sites.

e. Selection of a suitable geologic profile for measurement of the effect of sedimentary surface layer thickness on signal characteristics (Letter to AFTAC, 5 April 1966) - A search was made for a geologically suitable area in which to conduct this experiment. The requirement was for a fairly undisturbed sedimentary layer, overlying basement granite, which pinches out evenly from about 10,000 feet to zero thickness in a short lateral distance. On the basis of data gleaned from numerous well logs, as well as noise level and weather considerations, the Llano uplift area in Texas was selected as the most favorable of the 5 or 6 locations considered. The recording phase of this experiment has been postponed until the fall of 1966.

9.4 STUDY OF NEW DATA PROCESSING AND CALIBRATION TECHNIQUES

a. Evaluation of program ANGCOR (Memorandum Report, 20 August 1964) - A digital computer program was prepared to compute time-variable arrival angles and cross-correlation coefficients for digitized three-component data. The choice of time windows and lag sequences is very flexible. The program will be used in studies of particle motion, signal similarity, and signal-generated noise.

b. Extraction of signal-generated noise by subtraction of the "average" P wave from an individual signal (Memorandum Report, 6 November 1964 - An evaluation was made of a technique for separating signal-generated noise from true P-wave motion at a site. The method consisted of calculating the average P phase (sum/N) recorded at the Arizona sites around TFSO, then subtracting this average from each of the individual signals. Nine events treated in this manner demonstrated that the technique is not satisfactory, particularly when applied to an aggregate of only seven sites.

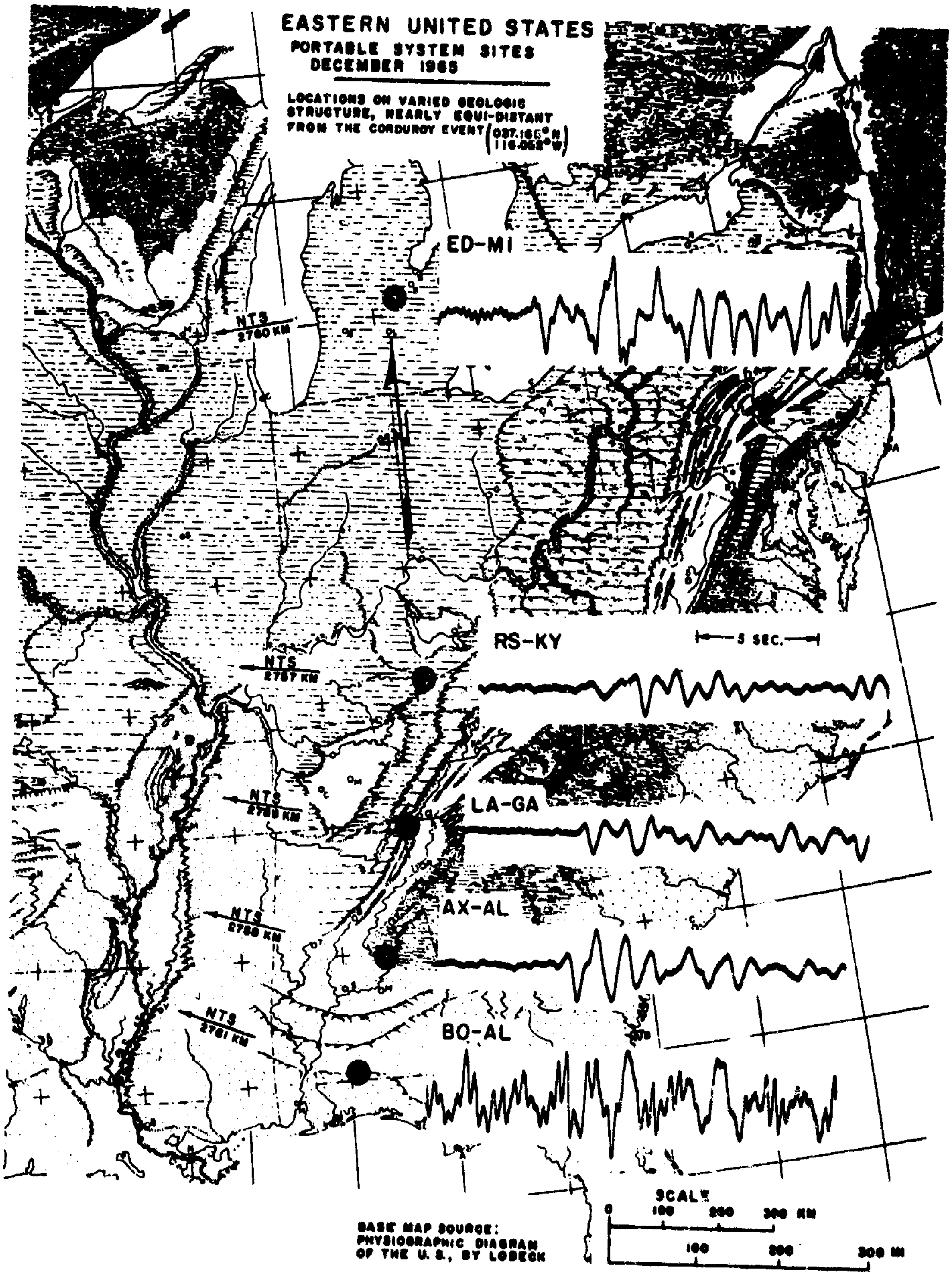

Figure 44. P phases from the CORDUROY event recorded by the LRSM portable systems, normalized to the same magnification at each site. All traces are short period vertical at a magnification of 56.2K (at 1 cps)

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c. Usage of extremely wide-spread LRSM stations as elements of a long-period array (Memorandum Reports, 8 September 1964 and 16 July 1965) - Two reports were issued showing the results of various experiments on the time-alignment of long-period P phases. LRSM sites scattered widely over the Western Hemisphere were successfully summed like array elements to improve the signal-to-noise ratio of long-period P phases. It was concluded that the factor of distance, whether epicentral distance or the distance between sites, is negligible so far as the similarity of long-period P phases is concerned, and that the standard Jeffreys-Bullen Seismological Tables are adequate to bring them into alignment. The studies also indicated that simple alignment of the long-period P phases recorded at various azimuths about an event can provide worthwhile information on the source mechanism. A demonstration of this technique is given in figure 45.

d. Evaluation of a calibration technique for multiple-element array systems (TR 65-11 and TR 65-127) - A study was made of a seismograph calibration technique based on the spectra of strong teleseismic P waves. The technique would have application to arrays of large numbers of seismometers, where it is impractical to equip each instrument with its own calibrator and the associated circuitry. A report (TR 65-11) discussing preliminary results obtained with an analog spectrum analyzer was issued in October 1965. Evaluations made, using a digital computer are summarized in TR 65-127. In brief, the studies show that the comparison-of-signal-spectra approach is feasible for frequencies below 1 cps, but becomes erratic at higher frequencies for several reasons.

e. A seismograph calibration technique and determination of seismometer parameters (in progress) - A special calibration function for application to seismometers with electromagnetic calibrators was devised and a practical evaluation of it begun. If successful, use of this function could substantially reduce the time required to determine whether or not a seismograph is operating within the specified tolerances for damping, frequency response, etc.

9.5 MISCELLANEOUS PROJECTS AND REPORTS

a. Interpolated J-B tables (TR 65-35) - The travel times for all body phases tabulated in the Jeffreys and Bullen (J-B) seismological tables were calculated by interpolation for distance intervals of 1 degree at each of the 14 established J-B focal depths. The only phases tabulated in such detail in the existing J-B tables are "P" and "S." Travel times were similarly derived for the phases "diffracted P" (P at distances beyond 105°) and "PKPPKPPKP," based on data extracted from the Gutenberg and Richter travel-time charts.

The calculations were effected by means of a program written for the Control Data 160-A digital computer. The program employed both linear 2-point

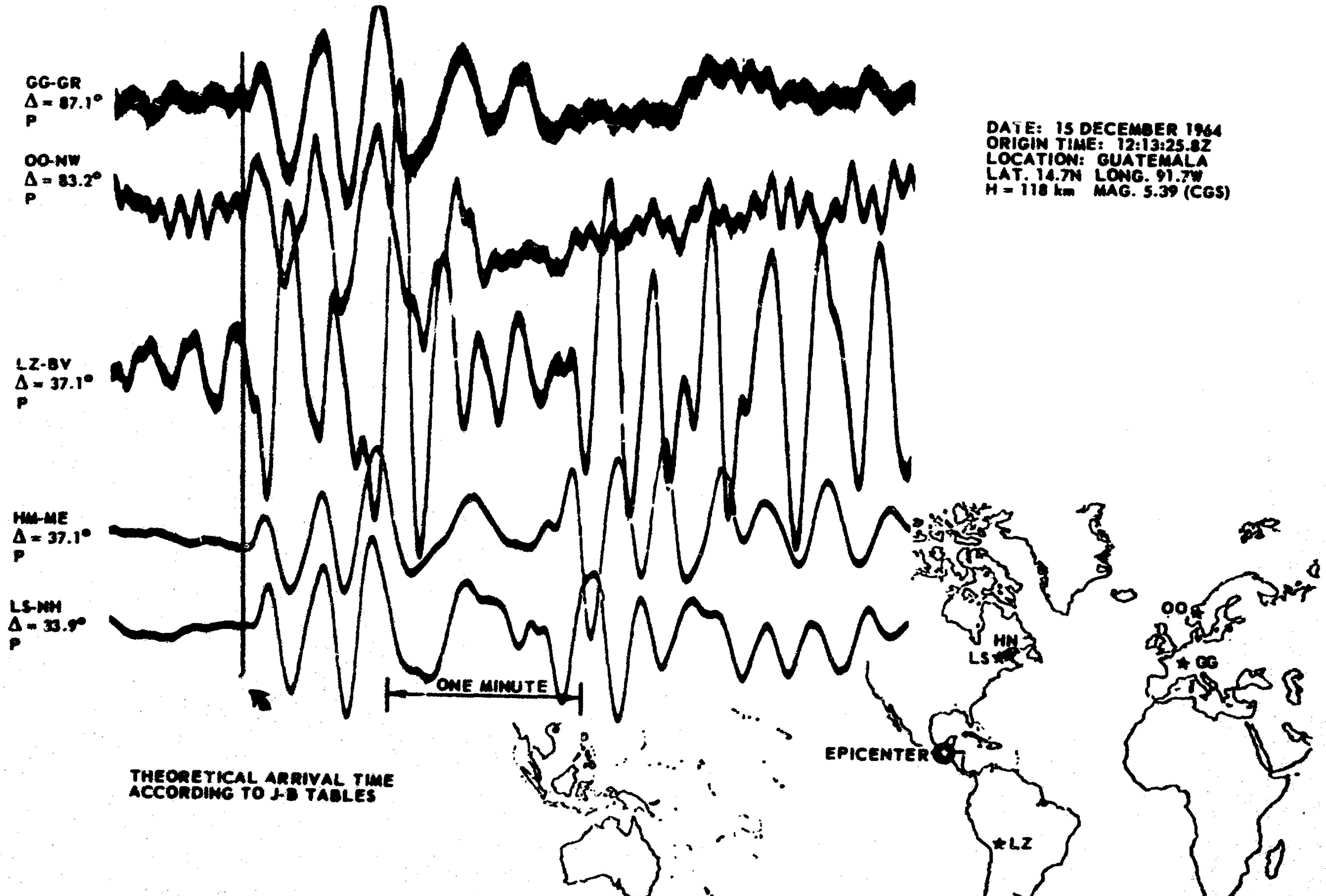

Figure 45. Time alignment of long-period teleseismic P phases recorded at various azimuths about the epicenter

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interpolation and Lagrangian 4-point interpolation techniques. Travel times were calculated covering the full range of existence of each phase, to the nearest tenth of a second, and were punched into cards. The times have been listed from the cards into a convenient reference form very similar to that employed for the "P" and "S" phases in the standard J-B tables. The cards remain available for computer applications.

b. Evaluation of SV2QB (TR 65-24) - An evaluation was made of the LRSM site at Schefferville, Quebec (SV2QB). Factors studied were the amplitude and frequency spectrum of the ambient noise, the amplitudes of teleseismic signals, and the detection capability of SV2QB relative to other LRSM sites.

c. Evaluation of a Geotech Model 20171 seismometer (TR 65-118) - Field tests were made in which a Model 20171 shallow-hole seismometer, located at various depths in a 152-meter hole, was compared with a Model 11167 deep-hole seismometer set at a depth of 150 meters in the same hole. Analysis of the data recorded showed that the characteristics of the shallow-hole seismometer compare favorably with those of the deep-hole seismometer. Time- and frequency-domain measurements of teleseismic signals recorded by both systems indicated similarity within their combined limits of calibration accuracy.

d. Geotech analog spectrum analyzer (TR 65-67) - A report was published on the Geotech analog spectrum analyzer, describing the accuracy of the system and the manner in which it operates. This equipment has been used to analyze LRSM data in the past and will continue to be used extensively in the future.

e. Bibliography of array literature (TR 65-114) - A bibliography of array literature (TR 65-114) was distributed. It lists over one hundred abstracted articles from various scientific journals, embracing the disciplines of seismology, acoustics, and radio. The articles are organized on the basis of content and field of application.

f. Evaluation of seismic data recorded by an amplified Wood-Anderson seismometer (TR 65-27) - The Amplified Wood-Anderson (WA) Seismometer, Geotech Model 17398, combines a standard 0.8-second WA seismometer with a modified Phototube Amplifier (PTA), Geotech Model 5240, and a Filter, Geotech Model 6824-1. This seismometer retains the response characteristics of the WA seismometer while greatly increasing its maximum magnification. In this report, an evaluation was made of its suitability for recording, at near regional distances, the seismic energy from 6 nuclear events and 2 earthquakes. The WA seismograms of these events were compared with seismograms of the same events recorded by short-period (SP) Benioff and broad-band (BB) seismographs operated within 50 feet of the WA at a location near Winnemucca, Nevada.

The magnetic-tape recordings of these signals were processed by a spectrum analyzer to provide Fourier Series spectrograms for frequency content comparisons. Magnitudes were also computed from the seismograms produced by each of these seismographs. The comparison of the seismograms, the spectrograms, and the magnitudes revealed the WA data to be of good quality and suitable for comparison with data obtained by the other seismographs.

g. Characteristics of instruments and seismic noise in two shallow holes at Hysham, Montana (TR 66-50) - During the months of August and September 1965, seismic data from 4 shallow-hole seismographs and 2 surface seismographs were recorded on magnetic tape at Hysham, Montana (HY-MA). The two seismometers, a Hall-Sears HS-10-1 and a Geotech Model 11167, situated in 500-foot holes, were each operated at six different depths. Processing was begun on both the signal and noise data obtained. The purposes of the experiment are to measure the attenuation of noise with depth in these shallow holes and to compare the operation of the HS-10-1 and the Geotech Model 11167 seismographs. A composite spectral presentation showing the attenuation of wind noise with depth in an HY-MA hole is given in figure 46. A technical report will be published in July 1966.

h. Hurricane noise study - During the early fall of 1964, the Atlantic and Gulf Coastal areas were battered by a series of hurricanes. A study of the background noise generated by DORA, HILDA, and ISBELL was conducted. Data were reviewed from the vertical short-period seismograms from 10 LRSM sites. The time period studied was from 1 September-25 October 1964.

No specific conclusions were reached as a result of this study. While the background noise level at all sites was appreciably higher during the storm period, the hurricanes were only a part of a larger weather system which blanketed the area occupied by the observatories. No microbarograph systems, from which data correlation might have been profitable, were installed at the LRSM stations.

10. RECOMMENDATIONS

10.1 REPLACE PHOTOCELL AMPLIFIERS WITH ALL TRANSISTORIZED UNITS

With the advent of the portable seismograph system in the LRSM program, it has been possible to record seismic events of interest on a sophisticated seismograph system with very little delay in transporting the equipment to the site and in preparing the system for operation.

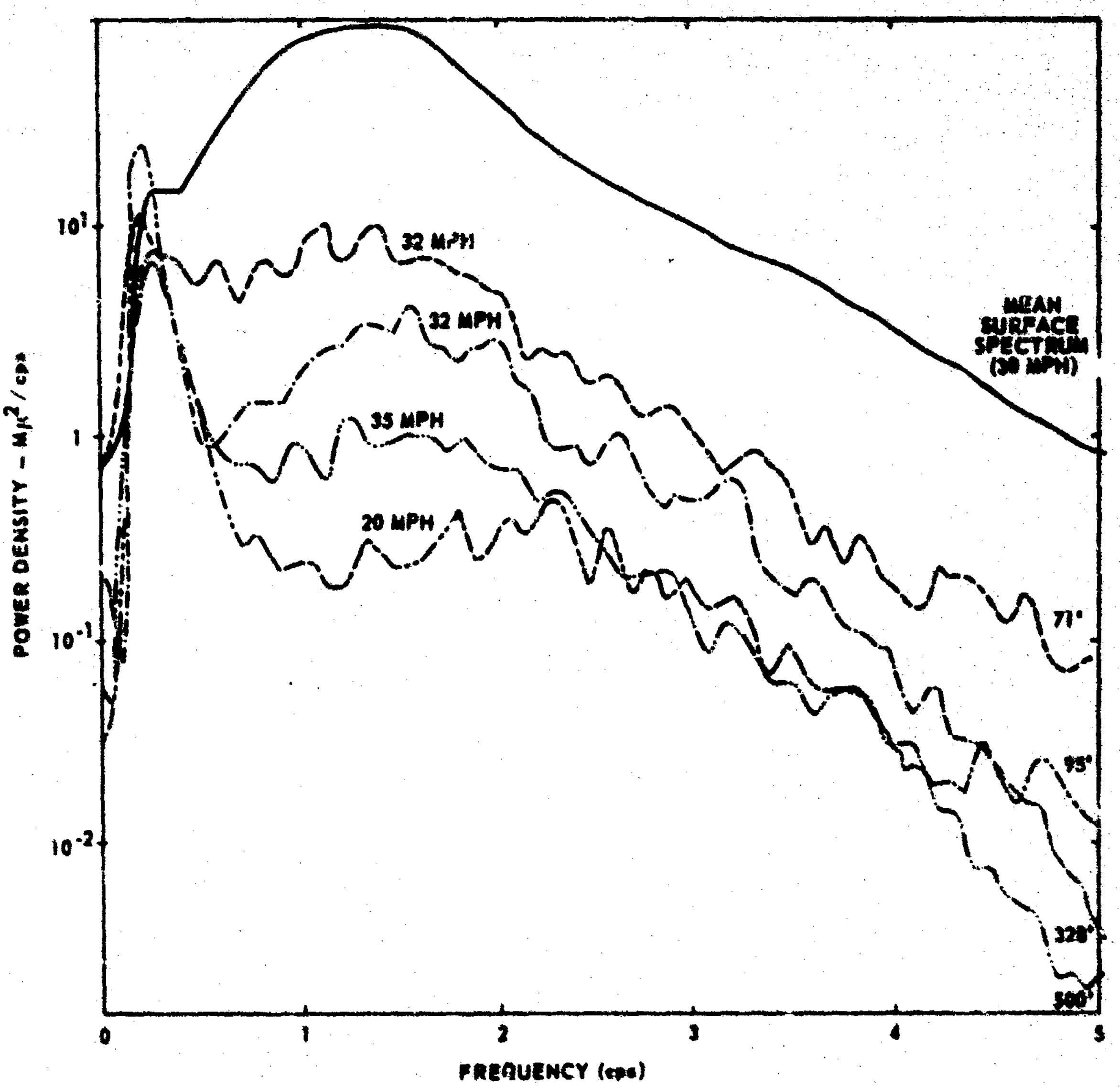


Figure 46. Power density spectra of noise on the surface and at various depths in the HY-MA shallow holes, during periods of high wind velocity. Mean wind velocities over the sample intervals are shown. The spectra are not compensated for seismograph frequency response

G 1750

At the time that these systems were introduced in the program, the most suitable amplifiers available for use in this type of portable system was a photocell amplifier (PCA). Since that time, significant strides have been made in the design of low-noise, low-frequency, solid-state amplifiers which are much more suited for use in this application. The use of these amplifiers in both the short-period and the long-period seismographs would significantly reduce the time now required to balance the PCA's each time the systems are installed. Their addition would also improve the overall reliability of the portable systems because of the inherent ruggedness of this type of amplifier.

We therefore recommend that solid-state amplifiers be used to replace the existing PCA's in the portable seismograph system. This should be accomplished by first incorporating this type of amplifier in 1 short-period and 1 long-period seismograph and operating these systems for several weeks in the field to prove the feasibility of this concept.

11. ADMINISTRATION

The material used in this report was gathered by the supervisory personnel of the LRSM program. These data were composited and the report written by Mr. Darrell C. Rasmussen.

APPENDIX 1 to TECHNICAL REPORT NO. 66-92

SPECIFICATIONS - 1/2 TON HEAVY-DUTY
PICKUP TRUCK

SPECIFICATIONS

1/2 TON HEAVY-DUTY PICKUP TRUCK

1. SCOPE

This specification covers a two-wheel drive 1/2 ton heavy-duty pickup truck for use in on-the-road and off-the-road service. This vehicle will be required to trail a loaded trailer by means of a ball hitch while carrying a load. It will operate on improved highways, on unimproved roads, and off the road in sand, dirt, rocks, mud, and snow. It will be required to operate in temperatures from -40°F to +120°F and at altitudes from sea level to 10,000 feet. Vendor standard or heavy-duty specifications are to be stated in proposals and upon acceptance by The Geotechnical Corporation Engineering Department will become a part of this specification. Replacement parts for this vehicle must be readily available from local garages and/or parts suppliers in remote ranching and farming communities. A shop's manual will be supplied with each vehicle.

2. PERFORMANCE

2.1 GRADEABILITY - With a 1900 lb payload, including hitchload, and trailing a 5000 lb trailer, this vehicle is to be able to start and to attain a minimum speed of 2.0 mph on a 20 percent grade with a surface rolling resistance of 100 lb per 1000 lb of vehicle and trailer.

2.2 SPEEDABILITY - With a 1900 lb payload, including hitchload and trailing a 5000 lb trailer, this vehicle is to be able to attain a minimum speed of 50 mph at the recommended cruising engine speed on a level improved road.

2.3 CALCULATIONS AND DEMONSTRATION - Vendor is to submit detailed specifications and calculations pertaining to conformance with 2.1 and 2.2. Input torque ratings for transmission, differential and rear axles will be supplied with bids. Vendor is to demonstrate performance of the vehicle.

3. LOAD

Payload to be either 900 lb centered in the bed plus 1000 lb trailer hitchload or 1900 lb centered in the bed. Vendor is to specify rated gross vehicle weight (GVW).

4. POWER PLANT

4.1 TYPE - In line, 6 cylinders, water-cooled, with minimum displacement of 250 cubic inches, or V-8 with displacement less than 330 cubic inches. Rated net horsepower of not less than 140 hp, rated net torque of not less than 225-ft-lb. Vendor to supply curves of engine rated hp and torque versus engine rpm.

4.2 CLUTCH - Heavy duty; vendor to specify diameter and surface area.

4.3 TRANSMISSION - Four speed synchromesh; vendor to state gear ratios.

4.4 COOLING SYSTEM - Heavy duty; vendor to specify capacity and radiator thickness and area. Heavy duty five-blade cooling fan and shroud will be supplied.

4.5 ANTI-FREEZE - Permanent type with protection to 40°F below zero.

4.6 OIL FILTER - Heavy duty; vendor to specify capacity.

4.7 AIR CLEANER - Heavy duty; vendor to specify capacity.

4.8 FUEL - Regular grade gasoline; vendor to specify capacity of fuel tank.

4.9 BORE AND STROKE - Vendor to specify bore, stroke and displacement.

5. CHASSIS

5.1 SPRINGS - Heavy duty, compatible with load and performance specifications; with overloads of the Mooney Type.

5.2 REAR AXLE - 3500 lb minimum capacity, positraction vendor to specify gear ratio.

5.3 FRONT AXLE - 2500 lb minimum capacity.

5.4 BRAKES - Four wheel heavy duty hydraulic, with mechanical emergency on rear wheels, vendor to specify surface area.

5.5 SHOCK ABSORBERS - Heavy duty.

5.6 TIRES -

5.6.1 Front - Two 6.50 x 16, tube type, 6 ply rating, nylon, highway tread.

5.6.2 Rear - Two 6.50 x 16, tube type, 6 ply rating, nylon, on-off road.

5.6.3 Spare - One 6.50 x 16, tube type, 6 ply rating, nylon, on-off road, side mounted.

6. CAB AND BODY

6.1 BODY - Standard pickup body.

6.2 SEATS - Full width.

6.3 REAR BUMPER - Heavy duty step type with hitch plate and 2-5/16 in. diam ball hitch, capable of withstanding 1000 lb hitchload and pull of 5000 lb, under conditions of on-off road service. Nominal hitch height will be 18 in.

6.4 HEATER - Heavy-duty-fresh-air heater and defroster.

6.5 WINDSHIELD WIPERS - Two speed or variable speed electric.

6.6 DIRECTIONAL SIGNALS - Front and rear, self-cancelling, flare-stat will be provided to flash all turn signal lamps simultaneously.

6.7 REAR VIEW MIRROR - Right and left folding extension arm mirror 5 in. x 7 in. head, and interior mirror.

6.8 SEAT BELTS - Two sets, installed.

7. ELECTRICAL

7.1 GENERATOR - 12 volt, dc, 30 ampere.

7.2 BATTERY - 12 volt, 54 ampere-hour.

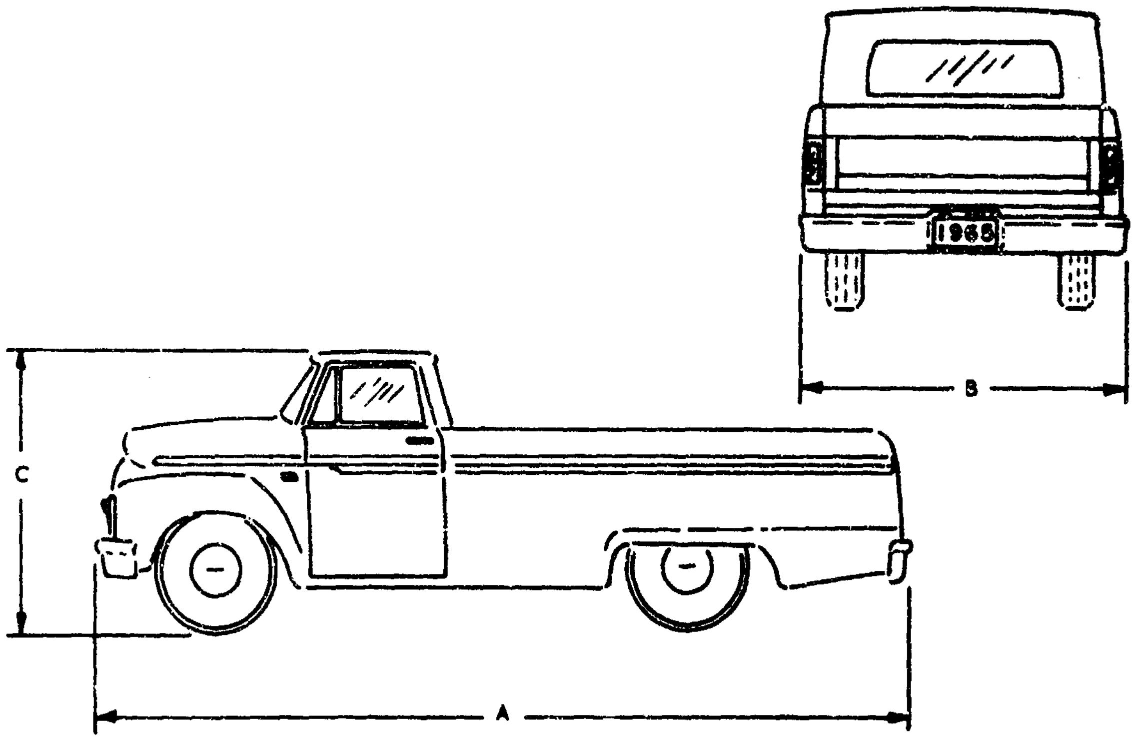
7.3 TRAILER CONNECTOR - A/7 - Way trailer connector, to fit Southwest Wheel and Manufacturing Company, Assembly No. 753, shall be provided and wired to furnish power for tail light, stop light, and directional signals. Geotech to furnish wiring diagram showing color code and pin numbers used.

8. WARRANTY

In addition to the manufacturers warranty covering truck and parts for a specified time and mileage, the vendor must guarantee that the truck will conform to the performance specifications per paragraphs 2.1 and 2.2 and the chassis specifications per paragraphs 5.1 and 5.2. The vendor

must guarantee that the vehicle will not overheat under the operational conditions specified in paragraphs 1, 2, and 3.

In the event that the truck is found not to conform to these specifications after delivery, the vendor will be required to bring the truck up to specifications at no cost to the customer, or the truck will be returned to the manufacturer for a full refund.



OVERALL LENGTH = A = 16 FT.

OVERALL WIDTH = B = 6 FT. 8 IN.

OVERALL HEIGHT = C = 6 FT. 0 IN.

TOTAL CUBAGE = 370 CUBIC FT.

TOTAL WEIGHT = 3,450 LBS.

NOTE: THESE DIMENSIONS ARE NOT ACTUAL. THEY ARE FOR SHIPPING PURPOSES AND INCLUDE 1 TO 3 INCHES FOR CLEARANCE.

Figure 1. 1/2 ton truck

G 1759

APPENDIX 2 to TECHNICAL REPORT NO. 66-92

SPECIFICATIONS - 2-1/2 TON HEAVY-DUTY TRUCK

SPECIFICATIONS

2-1/2 TON HEAVY-DUTY TRUCK

1. SCOPE

This specification covers a 2-1/2 ton heavy-duty truck for use in on-the-road and off-the-road service. The truck will be required to trail a loaded trailer of 27,000 lb gross weight by means of a ball hitch. The trailer will be 29-1/2 ft long, 12 ft high and 8 ft wide. It will operate on improved highways, on unimproved roads, and off the road in sand, dirt, rocks, mud, and snow. It will be required to operate in temperatures from -40°F to +120°F generally at altitudes from 500 ft to 7000 ft.

Vendor standard and/or heavy-duty specifications are to be stated in proposals and on acceptance by The Geotechnical Engineering Department will become a part of this specification.

2. PERFORMANCE

2.1 GRADEABILITY - Trailing a 25,000 lb trailer, this vehicle is to be able to start and to attain a minimum speed of 2.0 mph on a 30 percent grade with a road surface rolling resistance of 100 lb per 1000 lb of vehicle and trailer.

2.2 SPEEDABILITY - Trailing a 27,000 lb trailer this vehicle is to be able to attain a minimum speed of 50 mph at the recommended cruising engine speed on a level improved road with a road surface rolling resistance of 10 lb per 1000 lb of vehicle and trailer.

2.3 CALCULATIONS AND DEMONSTRATION - Vendor is to submit detailed specifications and calculations pertaining to conformance with 2.1 and 2.2. Input torque ratings of all transmissions, differentials and rear axles will be supplied. Vendor is to demonstrate performance of the vehicle.

3. LOAD

Payload to be approximately a 5000 lb trailer-hitch load, plus an additional 5000 lb carried over the rear axle. Vendor is to specify rated gross vehicle weight (GVW).

4. POWER PLANT

4.1 HORSEPOWER AND TORQUE RATINGS - Compatible with performance specifications, vendor to supply curves of engine rated horsepower vs engine rpm.

4.2 TRANSMISSION - Six speed automatic, Allison MT-40 transmatic or equivalent. Vendor to state gear ratios. Final decision on transmission type will be made after evaluation by Geotech personnel.

4.3 COOLING - Heavy duty, water; vendor to specify cooling system capacity and radiator thickness and area. Vehicle will not overheat when operating with specified full load at an ambient temperature of 120°F.

4.4 ANTI-FREEZE - Permanent type with protection to 40° below zero.

4.5 OIL FILTER - Heavy duty; vendor to specify capacity.

4.6 AIR CLEANER - Heavy duty; vendor to specify capacity.

4.7 FUEL FILTER - In line, accessible under the hood.

4.8 FUEL - Regular grade gasoline; vendor to specify capacity of saddle fuel tank(s). Capacity sufficient to provide a minimum range of 400 miles under full load conditions is required. Behind seat fuel tank will be removed or disabled if installed.

4.9 BORE AND STROKE - Vendor to specify: bore, stroke, and displacement.

5. CHASSIS

5.1 OVERALL LENGTH FROM CENTERLINE OF BALL HITCH TO FRONT BUMPER TO BE 19 FT, 6 IN. OR LESS.

5.2 SPRINGS - Heavy duty compatible with load and performance specifications.

5.3 REAR AXLE - 15,000 lb minimum capacity; vendor to specify gear ratio.

5.4 FRONT AXLE - 5,000 lb minimum capacity.

5.5 BRAKES - Four wheel heavy duty hydraulic with vacuum assistance and vacuum reserve tank to allow four stops without engine running, and mechanical emergency on rear wheels; vendor to specify surface area. Additional equipment for trailer brakes to be furnished per paragraph 8.4 of this specification.

5.6 TIRES

5.6.1 Front: Two 9.00 x 20, tube type, 10 ply rating, nylon hi-way tread.

5.6.2 Rear: Four 9.00 x 20, tube type, 10 ply rating, nylon on-off road type.

5.6.3 Spare: One 9.00 x 20, tube type, 10 ply rating, nylon on-off road type.

5.7 ROAD CLEARANCE - Minimum road clearance loaded to be 8-1/2 in.; vendor to specify minimum clearance.

5.8 WHEELS - All wheels to be interchangeable from outside to inside and front to rear.

6. CAB AND BODY

6.1 BODY - Vendors conventional cab, 6-1/2 ft x 8 ft platform with 18 in. solid 2 in. hardwood sideboards, contour fenders, mud flaps, clearance lights, spare tire rack, undercoating, wheel chocks w/rack and a steel storage box 12 in. x 12 in. x 24 in. installed under platform. Body will not extend past the centerline of the ball hitch.

6.2 FRONT BUMPER - Heavy duty with heavy-duty grill guard.

6.3 HEATER - Heavy-duty fresh-air heater and defroster.

6.4 WINDSHIELD WIPERS - Dual speed electric with window washer.

6.5 DIRECTIONAL SIGNALS - Front and rear self-cancelling.

6.6 REAR VIEW MIRRORS - Right and left folding extension arm mirrors approximately 6-1/2 in. x 16 in. head.

6.7 SEAT BELTS - Two sets.

7. ELECTRICAL

7.1 GENERATOR - 12 volt, 35 ampere alternator - minimum.

7.2 BATTERY - 12 volt, 53 ampere - hour.

8. ACCESSORIES

8.1 TRAILER CONNECTOR - A standard trailer (7-way) electrical connector shall be provided and wired per drawing No. 18109 to furnish power for trailer tail light, stop light, clearance lights, and directional signals.

8.2 Truck to be wired with clearance lights and driving lights to conform to standard ICC regulations with suitable controls and switches for the trailer lights outlined in 8.1.

8.3 Truck shall be equipped with a ball hitch capable of withstanding the forces exerted by the pull of a 27,000 lb trailer. Ball hitch diameter to be 2-5/16 in. Ball hitch height with truck loaded with specified weight in paragrph 3 is to be 24 in.

8.4 TRAILER BRAKES - Truck shall be equipped with the following additional equipment necessary to actuate vacuum over hydraulic trailer brakes:

(1) Vacuum hand control valve mounted on steering column to operate only trailer brakes.

(2) A low vacuum warning light and buzzer mounted on the instrument panel.

(3) A double manifold check valve mounted on the firewall will be provided.

(4) A shutoff cock mounted on firewall to shut off trailer vacuum control line.

(5) A synchronizing valve to operate trailer brakes when truck brakes are applied.

(6) A ball check valve between hand control valve and synchronizing valve control lines.

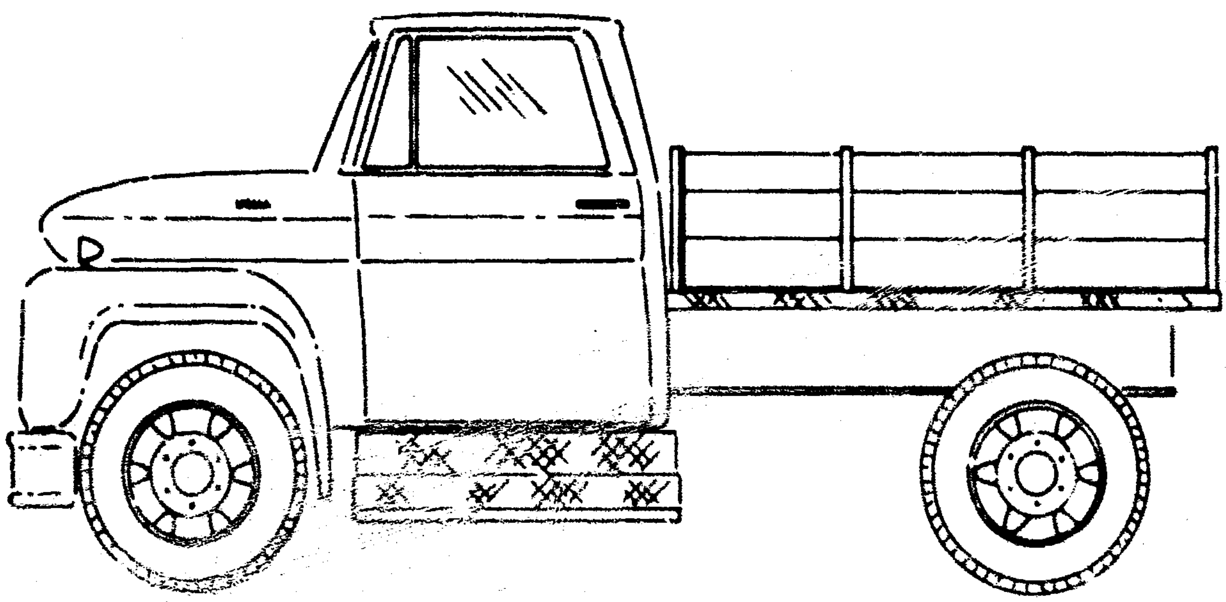
(7) One male and one female trailer brake vacuum hose coupling mounted at rear. Male coupling attached to vacuum supply line and female coupling attached to trailer brake control line. Coupling to be Midland part No. C-11453 and C-11454 or equivalent.

8.5 Vendor will supply a complete parts list, shop manual, and wiring diagram for the vehicle.

9. WARRANTY

In addition to the manufacturers warranty covering truck parts for a specified time and mileage, the vendor must guarantee that the truck will conform to the performance specifications per paragraphs 2.1 and 2.2, the chassis specifications per paragraph 5.1, 5.2, and 5.3 and the cooling system specification per paragraph 4.4.

In the event that the truck is found not to conform to the above specifications after delivery, the vendor will be required to bring the truck up to specifications at no cost to the customer, or the truck will be returned to the manufacturer for a full refund.



OVERALL LENGTH = 17 FT.

OVERALL WIDTH = 7 FT. 11 IN.

OVERALL HEIGHT = 7 FT. 10 IN.

TOTAL CUBAGE = 1,050 CUBIC FT.

TOTAL WEIGHT = 8,730 LBS.

NOTE: THESE DIMENSIONS ARE NOT ACTUAL. THEY ARE FOR SHIPPING PURPOSES AND INCLUDE 1 TO 3 INCHES FOR CLEARANCE.

Figure 1. 2-1/2 ton truck

G 1760

APPENDIX 3 to TECHNICAL REPORT NO. 66-92

SPECIFICATIONS - KRISTI SNOW VEHICLE, KT-3

SPECIFICATIONS - KRISTI SNOW VEHICLE, KT-3

Specifications Model KT-3

Dimensions:	Length 11'; height 5'9" width 7'4"
Weight:	2, 095 lbs (empty)
Bearing pressure:	.46 psi
Capacity:	5-6 passengers (accommodates a stretcher)
Max. gross weight:	3, 595 lbs
Draw-bar pull:	2, 000 lbs
Performance:	Speed: 1/2 to 20 mph Range: 20 gallon tank, 15 to 18 hours of operation. Climb: Maximum: 100% grade with full load. Snow maximum: 70% grade with full load. Side hill: 60% grade (Soft snow).
Tires:	8-6 ply 6. 90 x 9 heavy duty.

BODY: The fiberglass body is heavily reinforced at places of strain with a thick coat of red pigment, moulded-in, insuring a beautiful and durable finish. A welded one-piece steel frame is riveted to the lower body and supports the engine and the suspension members. Louvered openings in engine compartment facilitates cab temperature control.

ENGINE: An air-cooled 36 horsepower VW engine is standard equipment. Fuel consumption is 1-1/2 gallons-per-hour, maximum

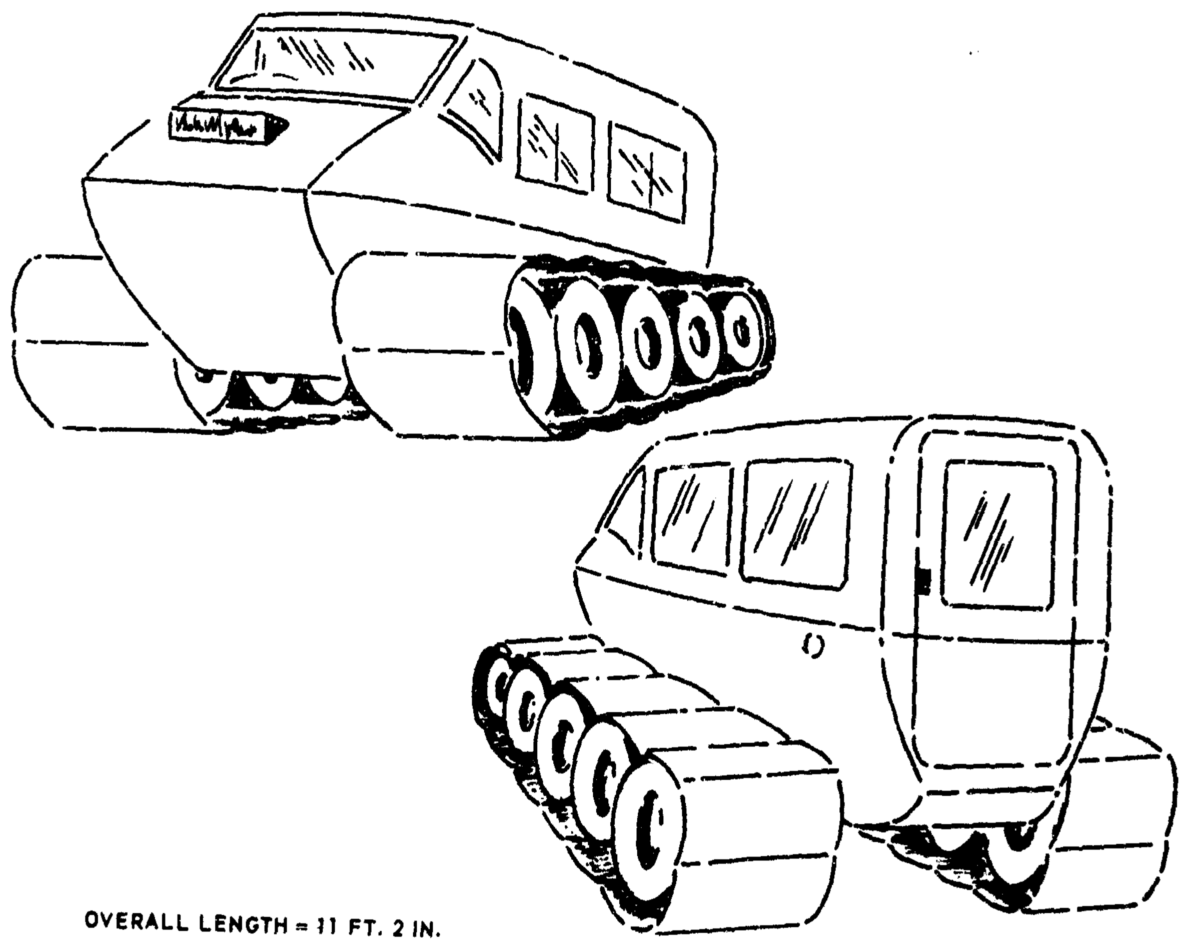
TRANSMISSION: Eight speeds forward . . . four reverse, with High-Low Range. Ratio is 7:1.

STEERING: Positive-control differential makes turns possible within ten-foot radius. Using both control levers simultaneously, the Kristi may be stopped and held in position on the steepest grade.

SUSPENSION: The KRISTI "ski-action," with finger-tip control, will maintain the body in a level position on side-grades up to 25%. A four-point hydraulic

suspension with coil spring mounts, allows the entire track-carrier to automatically flex over twisting terrain, while the cab maintains a comfortably balanced position. The KRISTI KT-3 has heavy-duty, tandem-paired boggies for increased capacity and smoothness. The track is tightened by use of a jack-screw on the rear tandem.

TRACK: A moulded rubber-aluminum sprocket drives the track through stainless steel cups, mounted on the high hickory cleats. The main belts are five inch, five ply, nylon-cotton conveyor belting with flexo fasteners. Outside belts of the twenty-four inch track are looped to alternate cleats for maximum traction and elimination of side-slip. All cleats are treated and faced with a hard surface weld on fastening nuts to insure longer wear and provide additional traction on ice.



OVERALL LENGTH = 11 FT. 2 IN.

OVERALL WIDTH = 7 FT. 6 IN.

OVERALL HEIGHT = 5 FT. 11 IN.

TOTAL CUBAGE [illegible] CUBIC FT.

TOTAL WEIGHT = 2,095 LBS. (EMPTY)

NOTE: THESE DIMENSIONS ARE NOT ACTUAL. THEY ARE FOR SHIPPING PURPOSES AND INCLUDE 1 TO 3 INCHES FOR CLEARANCE.

Figure 1. Kristi snow vehicle, KT-3

G 1761

APPENDIX 4 to TECHNICAL REPORT NO. 66-92

SPECIAL PRESENTATIONS GROUP MAJOR EQUIPMENT INVENTORY

LRSM SPECIAL PRESENTATION EQUIPMENT

DIGITIZING EQUIPMENT:

Quantity	Description
1	Analog-Digital Converter: Applied Development Corp.; 10-bit accuracy; .1, 1.0, 10, 25, 50, 100, 250, 500, 1000, and 10,000 samples/sec rates; used either on line with digital computer or off line with Teletype BRPE 11 paper tape punch.
2	Digital-Analog Converter: Applied Development Corp.; 10-bit accuracy; used on line with digital computer
1	Multiplexer: 10 channel, 10 kc rate.

ANALOG EQUIPMENT:

Quantity	Description
2	Tape Transports: Honeywell LAR7400; record and playback; 1 inch tape; .3, .6, 1.5, 3.0, 15.0, 30.0 and 60.0 in./sec.
1	Tape Transport: Ampex Model FR100B; read only; .3, .6, 30.0 and 60.0 in./sec.
1	Tape Transport: Ampex Model 306-7; record only; 30.0 and 60.0 in./sec.
2	Filters: Krohn-Hite Model 330A(R)-8; bandpass with upper and lower cutoff frequencies continuously variable; 6, 12, 18 and 24 db/octave cutoff rates; .02 - 2,000 cps.
3	Analog Computers: EAI TR-10.
1	Recording Oscillograph: CEC Model 5-124; 7 inch light sensitive paper; 6 channels; .25, 1, 4, 16, 64 in./sec paper speeds.
1	Recording Oscillograph: CEC Model 5-119; 7 or 12 inch film or paper; 12 channels; .16 - 169 in./sec.

Quantity	Description
3	Helicorders: Geotech Model 2484
2	Develocorders: Geotech Model 4000.
1	Magnetic Mirrograph: Techno Instruments Co., TI-401A; 8 channel.
2	Delay Line: AD-YU Electronic Lab, Inc.; Continuously variable delay; 1000 u sec max. delay.
1	Time Encoder: Geotech Model 11667.
1	Time Code Tape Search Unit: Hyperion Industries, Inc.; Model HI-231V-B; VELA code only.
1	Oscilloscope-Record Camera: Fairchild Type 321-A; 35 mm film; 1.6, 4.9, 14.8, 44.4, 133.3, 400, 1200, 3600, and 10,800 in./sec.
2	X-Y Recorder: Houston Instrument Corp. Model HR-95; 8-1/2 x 11 inch.
1	Spectrum Analyzer: Hewlett-Packard Model 302A; wave analyzer, used with Geotech spinning reproducer; 0-10 kc; 110 sec data maximum.

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13. ABSTRACT

The progress of the Long-Range Seismic Measurements Program (LRSM) during the period 1 July 1964 through 31 March 1966 is described. The data contained in the report are categorized along the same lines as the organization of the LRSM program, namely: operations, data processing, equipment modifications, equipment and seismogram evaluation, and special projects.

During November 1964, a program was initiated whereby several mobile observatories were transferred from the LRSM Program to other organizations. As a result, the number of observatories within the group was decreased from 39 to 16. Emphasis continues to be placed on the advantages realized by the operation of portable seismograph systems, and during the report period, the six LRSM portable systems were extensively used.

Several equipment modifications were incorporated into standard system configuration. These modifications included the installation of remote centering and free-period adjustment units on all long-period seismometers, the installation of one experimental multiconductor cable system and one prototype lightning protection system, the replacement of the tape transport supply motors with a viscous brake type of supply unit, and the installation and integration of telemetry equipment in the LASA and TFSO Extended Array observatories.

The established equipment and seismogram evaluation programs continued to lend important support to the field teams. These efforts have been a major causal factor in the professional status achieved by the field personnel.

The number and variety of specialized uses to which LRSM data can be put have grown steadily. Studies which have been undertaken and completed by the Evaluations Group include surveys of seismological bulletin data, effects of site geology on signal and noise properties, and new data processing and calibration techniques.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Long-Range Seismic Measurements Program						
VELA Uniform						
Seismic Recording Systems						
Detection of Seismic Signals						

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